(PUBLISHED QUARTERLY)

Journal of the Council for Scientific and Industrial Research.

Vol. 3. MAY, 1930. No. 2.

The Preservation of Citrus Fruit.

Progress Report of the Citrus Preservation Committee.

The Committee was formed by the Council in 1928 to conduct experimental work on methods for the preservation of citrus fruits. The main reason for its formation was that those connected with the production of citrus fruit in Australia had considered that the industry could be expanded considerably if a means could be discovered whereby the fruit could be made available out of season, and whereby its condition could be maintained in storage for a sufficiently long period to render its export to other countries commercially feasible. Many attempts aimed at the development of such a process had been made previously, notably in America, where no little success had been obtained. The application of American methods under Australian conditions, however, had in some cases not yielded the expected good results.

The personnel of the Committee that was set up is as follows:—

Associate-Professor W. J. Young, University of Melbourne (Chairman).

W. D. Bracher, Esq., Victorian Railways.

Captain D. Halhed, Victorian Citrus Growers' Association.

J. Hepburn, Esq., Victoria Dock Cool Stores, Department of Agriculture.

W. Ranger, Esq., Manager, Committee of Direction of Fruit Marketing, Queensland.

F. M. Read, Esq., Department of Agriculture, Victoria.

Miss E. Archer, Council for Scientific and Industrial Research (Secretary).

The actual work has mostly been carried out under the supervision of Associate-Professor Young and Mr. Read. The necessary fruit has been placed at the disposal of the Committee by the Victorian Railways, the only cost to the Committee being for fruit that was actually lost during the experiments. Through Mr. Hepburn, the Victorian Department of Agriculture has placed the facilities of the Cool Stores at the disposal of the Committee at all times, and has

supervised the storage of the fruit. The thanks of the Committee are due also to Mr. Tamlin, of the Refreshment Branch of the Victorian Railways, who has helped in procuring the fruit, and in other ways.

The experiments have been conducted on what is considered a commercial scale; for, although some 400 to 800 cases have been used in each experiment, the fruit has been handled in such a manner, and at such a rate, as would be used were there many thousands of cases to be treated. The cold storage, too, has been for the most part carried out in the commercial chambers alongside commercial fruit.

It is therefore the more gratifying that material success has been obtained, particularly with late Valencias, which were kept during the 1928-29 season in almost perfect condition for 155 days, and again this season (1929-30), the fruit which is still in store promises to keep equally as well.

A careful study of the treatments given and the results obtained shows that one of the most important factors in determining the storage life of the fruit is the manner in which it is handled during the picking and packing process. From the very first experiment, it was obvious that fruit which had been cut from the trees with clippers, and handled throughout the sizing and packing with gloves, stood a much better chance than fruit handled in the ordinary way.

In all, two seasons' tests with Washington Navel oranges have been completed, whereas only one season's tests with Valencias have been completed, and those of a second are still in progress. With certain differences, the fruit has been subjected to the same treatments in each set of experiments, and the variations in the results obtained are, therefore, very interesting. A special study of the moulds attacking the fruit has been made by Mr. S. Fish, Assistant Plant Pathologist, Department of Agriculture, Victoria, but the results of this are not yet complete.

I. Description of Apparatus and Process.

From the commencement, the idea has been to test the effect of the preliminary washing of oranges with various solutions in preventing attack by moulds during subsequent cool storage of the fruit.

The apparatus used for the washing has been lent to the Committee by the Lightning Fruit Grader Co., Melbourne. It consists of a steam-heated tank for the preliminary soaking of the fruit in the various solutions, which are generally maintained at temperatures of from 110° Fahr. to 115° Fahr. From this tank, a conveyor carries the fruit to revolving brushes, over which the oranges pass to remove any loose dirt from the surface. This washing process is assisted by a number of jets of water playing on the fruit during its passage over the brushes. The oranges then pass into a long tank, also containing the solution and heated with steam to 110° Fahr. to 115° Fahr., where a series of moving paddles submerge the fruit and move it along the length of the tank under the surface of the solution. The fruit is immersed in the first tank for about three minutes, and about five in the second. From the second tank it passes over a revolving towel dryer. Half of each batch is then put through an ordinary sizing machine without further treatment, and is wrapped in paper and packed in standard export cases. The other half, before storage, is

coated with a fine film of paraffin wax by spraying with a solution of wax in kerosene from a paint spray as the fruit rolls down on to revolving brushes, which remove the surplus fluid.

Prior to its use in the first experiment, the above apparatus had not been in operation in Australia, and it was found, as the experiments proceeded, that various adaptations and modifications were necessary.

One modification, which packing sheds may find particularly useful, is the provision of loose towels to lie on the fruit as it passes over the revolving towel dryer. This revolving towel soon becomes so wet that it does not dry the fruit, merely removing excess moisture. If dry towels are tacked on the machine so that they rest loosely on the fruit, the efficiency of the apparatus is increased enormously, and the fruit can be actually dried. These loose towels, which should be made to fit the machine, need to be changed and dried as soon as fruit coming from the dryer points to the necessity.

When the treatment is completed, the fruit is placed in cool store, and an investigation is made periodically by carefully examining each orange in several cases in each batch, and the percentage and cause of wastage is recorded.

2. First Experiment—Washington Navel Oranges.

Process.—The first experiment was commenced in August, 1928, the fruit used for it being picked from orchards in the Murray districts, of Mildura, Irymple, and Curlwaa. In all the experiments, records of the atmospheric conditions were taken in the orchards at the time of picking and during the journey to Melbourne. For this first experiment the fruit was all sized in packing sheds in the neighbourhood of the orchards, packed into boxes without wrapping in paper, and despatched to Melbourne. It was already known from the work of other investigators that careful methods of picking led to the fruit standing up better under storage conditions, but it was considered desirable to obtain a quantitative measure of the betterment in storage qualities under Australian conditions. One half of the fruit from each orchard was accordingly handled in the ordinary way followed in groves in the districts, whereas the other half was handled with gloves throughout the picking, sizing, and packing. There were, therefore, two batches of oranges from each orchard. Each of these batches was subdivided into eight groups, and a group from each batch submitted separately to one of the following processes:—

1. Untreated.
2. Coated with paraffin without preliminary washing.
3. Washed in water, but not coated with paraffin.
4. Washed in water, followed by a paraffin coating.
5. Washed in sodium bicarbonate 5 per cent. solution.
6. Washed in sodium bicarbonate 5 per cent. solution, followed by a paraffin coating.
7. Washed in a borax 5 per cent. solution.
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There were, therefore, finally two lots, each of eight groups of cases, each group consisting of oranges from all five orchards separately cased, one lot of eight having been carefully handled, and the other

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handled in the ordinary way. Unfortunately, owing to unfamiliarity with the apparatus, and the necessity for making various adaptations and modifications, there was considerable delay in this first experiment before the processing was completed and the oranges finally placed in the cool store. This is, however, the only time such a delay has occurred. The oranges were then stored in the Government Cool Stores, Victoria Dock, and maintained at 38° Fahr. They were examined at intervals, and in each inspection about five cases of each treatment were counted, that is, from 300 to 600 oranges.

Results.

The fruit which had undergone any of the washing processes was very much more attractive in appearance than the untreated fruit, whilst this was further enhanced by the application of the wax which put a shine on the fruit. Counts were made at intervals of 24, 37, and 76 days from the first day of storage. The percentage of fruit showing any signs of decay due to moulds or any other causes was noted.

From the first, it was obvious that the fruit which had been carefully handled had better keeping qualities than the fruit which had been handled in the ordinary way. In the untreated fruit, which had not been carefully handled, there was a loss of 11.8 per cent., 25.5 per cent., and 60 per cent. in 24, 37, and 76 days respectively, whereas in the carefully handled fruit there was a loss of only 3.3 per cent., 13.2 per cent., and 48 per cent. at each of the three counts.

The results from the various methods of washing were not in any way conclusive. In the early counts, the only process showing any indication of an advantage over the untreated fruit was that in which both borax and paraffin were used. In the carefully handled fruit, at 24 days there was a loss of 1.7 per cent., as against 3.3 per cent. in the untreated, and in the ordinarily handled, a loss of 3.0 per cent., as against 11.8 per cent. in the untreated. This difference was less marked in the November count after 37 days, but it was observed that the moulds in the borax and paraffin fruit, although present, were largely pin points as compared with much larger infections in the untreated fruit.

At the December count of 76 days, there was no advantage in the treated fruit; there was a very large wastage in all the batches, and in fact the untreated showed slightly less wastage than the treated.

Throughout the experiment, a special count was kept of the percentage of browning appearing in the carefully handled fruit. The figures obtained, however, were so variable that no conclusions could be drawn.

The main wastage throughout was due to two moulds, *Penicillium italicum* and *P. digitatum* (the blue and green moulds respectively).

3. Second Experiment—Valencia Oranges.

For this experiment, the oranges were all obtained from one grove in Merbein. They were picked in December, 1928. As the first experiment had shown so clearly the advantage of carefully handling the fruit, it was decided to use only fruit which had been picked with clippers and handled throughout with gloves. It was also decided not to allow the fruit to pass through the ordinary packing sheds. It was

accordingly packed loosely into boxes in the grove, and these were nailed up and sent to Melbourne without any sizing and grading in the local shed. It was decided to abandon the treatment of washing with water, and to substitute washing with sodium sulphite in three concentrations, namely, 1 per cent., 2.5 per cent., and 5 per cent. Otherwise, the treatments were the same as in the first experiment.

Counts were made at intervals of 26, 65, 90, 124, and 155 days respectively. The fruit in all the lots kept remarkably well up to the 124 days of storage. There was, however, a very marked collapse of the fruit between 124 days and 155 days, but each of the treatments—(i) with borax and paraffin, and (ii) with bicarbonate and paraffin—had a distinctly good effect, the percentage of collapse with these treatments being reduced from 70 per cent. to 33 per cent. and 37 per cent. respectively. This was specially marked after 124 days, and inquiries made of Melbourne fruit merchants in regard to a lot of 25 cases which had been treated with borax and paraffin, and then stored for four months, elicited the information that the fruit was worth up to 30s. per case, and that they would be willing to pay that amount for it.

The main cause of wastage in this experiment was found to be due to a type of rot which attacked the stem end of the fruit, and in a large number of instances extended down the central pith. This was first noticeable after one to two months' storage as a browning of a small area around the button, usually circular, and up to half an inch in diameter. At this stage, it appeared very similar to the usual skin browning of oranges in storage, and did not affect the general health of the fruit.

After three months, many of these areas began to show definite infection with *Alternaria citri* (Pierce), the black spores of which showed out freely between the rind and the flesh of the fruit, and down the central pith. Two other fungi were also present to a small extent in much the same manner—namely, a *Penicillium* sp., somewhat similar to *P. digitatum*, and a *Fusarium* sp. The former produced a green central rot, and the latter a pink.

A very important point which has not yet been established is whether the early browning—termed, for want of a better name, " Sore Eye "—is an early manifestation of the fungus; or whether the fungus only attacks areas showing this injury. The blue and green moulds prevalent in the former experiment were very little in evidence, except in the bisulphite-treated fruit. In many cases, attack by these moulds came after collapse of the fruit, a collapse which was apparently caused through the fruit using up its own storage materials. To show the rate of wastage, a case of each batch was kept to extinction. These were first counted after 65 days, and subsequently examined periodically, all moulds or collapsed fruit being removed until the wastage reached 100 per cent. At 248 days, wastage was complete. At 155 days, the only lots not showing over a 60 per cent. wastage were those treated with borax and paraffin, or bicarbonate and paraffin.

4. Third Experiment—Washington Navels.

It was decided that in the second season's experiment with Washington Navels, it would be as well not only to test the washing treatments as formerly, but also to do some special experiments varying the methods of packing, and varying the temperature at which the fruit was stored.

All the fruit was picked with clippers in the same orchard on the 26th and 27th June, 1929, and handled with gloves. In order to test further the effect of eliminating the packing sheds, the major portion of the fruit was packed loosely into cases in the orchard and sent straight to Melbourne. The remainder was sent to the packing shed and treated as detailed below in the description of the packing experiment.

Washing Experiment.

The fruit sent direct to Melbourne was treated as in the two earlier experiments, except that for the sodium sulphite used in the second experiment salicylic acid was substituted. The oranges were all in storage by 6th July, and counts were made on 19th August after six weeks, and again on 25th September after eleven and a half weeks.

Most of the wastage was due in this experiment to blue mould (*P. italicum*), whereas green mould and stem-end rot were rare. All treated fruit, with the exception of that treated with salicylic acid and paraffin, showed much less mould than the untreated fruit, but little difference was observed between the treatments.

The manner of attack of the moulds was very different from that observed in previous experiments. In most cases, the infection followed on some collapse of the skin, and occurred in a number of small points, the typical "mouldy orange" being rare.

A condition of "collapsed skin" was very prevalent, and was the chief cause of wastage. It did not seem to be affected by the treatment. The skin had lost colour, had become a pale-yellow, dull in appearance, and mottled similar to the appearance of oranges seen in the groves after severe frost. It appeared to precede a general collapse, and in many cases moulds had attacked the fruit subsequent to this condition. It is possible that frosts which had been experienced before the fruit was picked contributed to this.

Packing Experiments.

The results of the packing experiments can be best shown by tabulating the percentage losses at eleven and a half weeks.

EFFECTS OF DIFFERENT METHODS OF PACKING AFTER ELEVEN AND A HALF WEEKS' STORAGE.

—	Moulds.	Collapse.	Skin Collapse.
Lot—	%	%	%
(1) Packed in dumps in packing shed at Merbein and stored as received	45	1	45
(2) Packed in standard cases at Merbein packing shed. Stored as received	61	less than 1	34
(3) Picked into cases in grove, stored loose in dumps without treatment	4	1	56
(4) As 3, but graded, repacked and wrapped in Melbourne	25	1	30
(5) As (1), but treated afterwards with borax and paraffin and repacked in dumps wrapped	3	14	24
(6) Picked and railed to Melbourne as (3), then borax and paraffin, wrapped, packed ..	4	11	51
(7) As (6), borax and paraffin stored loose, wrapped	1	4	34
(8) As (6), borax and paraffin, stored, loose, unwrapped	1	6	3

The following conclusions can be drawn from this table:—

(i) Lots (1) and (2) packed in the local shed showed a high percentage of mould infection as compared with those not packed there.

(ii) Even the fruit graded and packed in Melbourne, but without further treatment (lot 4), showed 25 per cent. loss by mould. This indicates that even the most careful packing prior to storage damages the fruit somewhat.

(iii) Contrary to a very general belief, fruit brought down loose in boxes, and stored in that condition (lot 3), was not injured by transportation in such condition; but showed very little mould.

(iv) Some of the better-keeping qualities of the unwrapped fruit may have been due to sweating taking place during transport with a hardening of the skin. This point is being investigated in subsequent experiments.

(v) Comparison between lots 1 and 5, and again between 4 and 6, discloses that treatment with borax and paraffin was very beneficial.

(vi) Fruit stored loose after treatment, lots 7 and 8 were better than lot 6, which was packed. This has been the case in all the experiments.

(vii) Comparison of lot 7 with lot 8 shows that the unwrapped fruit suffered less skin collapse than the wrapped; but, in view of the fact that lot 3, unwrapped, showed a high percentage of skin collapse, this result is not regarded as significant.

Storage at Different Temperatures.

Oranges, both untreated and after treatment with borax and paraffin, were stored at 32° Fahr., 38° Fahr., and 42° Fahr. to 45° Fahr., and examinations were made after eleven and a half weeks and fifteen weeks.

After eleven and a half weeks at 32° Fahr., practically all the fruit showed a collapsed appearance, and was very bitter in taste, and unsaleable. At 38° Fahr., the percentage of mould loss was low, but a marked feature was the collapsed condition of the skin, previously referred to. Even at 38° Fahr., the bitter taste occurred in some of the fruit.

At 45° Fahr., all the oranges were in excellent condition, and the skins showed no sign of the collapsed appearance. After fifteen weeks, the total wastage through every cause was only 5 or 6 per cent. in both the treated and untreated fruit. Practically no browning was observable. Both in appearance and taste, these oranges were excellent. They contained practically the same concentration of sugar as when they were put in store, but the acid content had fallen from 15 to 10 cc. of tenth normal acid per 10 cc. of juice.

All the fruit used in this experiment for storage at different temperatures had been carefully picked, and had not passed through the packing sheds.

5. Conclusions.

Although the experiments have not as yet been conducted over a sufficient number of seasons for the Committee to be able to show conclusively that its objects have been attained, the Committee has demonstrated a method of very materially reducing the loss that is usually experienced in Australia when oranges are stored for any length of time.

It has been amply proved that, in order to be able to store Navels in perfect condition for from two to three months, and Valencias for an even longer period, it is only necessary to handle the fruit with much greater care than is the usual practice in Australia from the time it is picked from the tree until it is placed in storage, and to protect it from all ordinary sources of mould infection.

The results that have been obtained by washing with borax and with bicarbonate, and subsequent spraying with paraffin, are also encouraging. Before the process can be definitely recommended, however, it will be necessary to repeat the experiments over several seasons. The varying weather conditions encountered in the ripening of the fruit may well affect its storage properties. There are also other factors, such as maturity at time of picking, &c., which require consideration before definite conclusions can be drawn.

Noogoora Burr in Queensland.

(Notes from a Report by Jean White-Haney, D.Sc.)

Dr. White-Haney has completed her inquiries into the extent, &c., of the Noogoora burr infestation in Queensland referred to in a previous issue of this *Journal* (Vol. 2, No. 2, p. 116). She has furnished a very full report on the matter to Dr. B. T. Dickson, Chief of the Division of Plant Industry. The following extracts have been drawn from that report.—Ed.

1. Introduction.

Noogoora burr belongs to the group commonly known as cockleburs or clot-burrs, and technically as *Xanthiums*. A close relative is Bathurst burr, which is *Xanthium spinosum*. The name Noogoora burr arose because it is generally accepted that this weed was first introduced into Australia at the Noogoora Station, Queensland, in the early sixties of last century. The evidence indicates that it arrived with cotton seed, but whence the cotton seed actually originated has not been determined, although it was American cotton. By 1879, it is recorded that 500 acres of the Noogoora Station were overrun by burr, and from there it has spread, at first slowly, but later with increased momentum, until now it is a serious pest plant.

Moisture is essential for its growth, and it mainly occurs on the banks of rivers, creeks, and bore drains, on the edges of ponds, or of depressions in which water tends to collect. It is also commonly observed in localities subject to inundation by floods. In those places situated a considerable distance from water-courses or ponds, &c., in which the burr has been seen to grow in any abundance, the soil is such that it becomes boggy with every shower of rain, and the annual average rainfall reaches at least 24 inches.

2. Present Distribution in Queensland.

As the plant is an annual, its distribution will naturally vary from year to year according to the season and to the climatic conditions. No hard-and-fast limit can therefore be laid down as to its definite boundaries in the State. It occurs up the east coast from the New South Wales boundary to Mirriwinnie, in the neighbourhood of Cairns, which at the present time appears to be about its northern coastal limit. It extends west from Cairns as far as the Gilbert, Etheridge, and Einasleigh Rivers, and has spread for over 100 miles along the Gilbert, north-west from its junction with the Einasleigh. Many of the islands in this river are densely infested with burr. The western boundaries appear to be:—On the north, the Flinders River, the banks of which are in many places exceedingly thickly beset with burr which, however, begins to thin out about Quiltes; north from Manfred; and on the banks of the Stawell River extending to Burleigh, after which few plants occur. It is somewhat thinly distributed in isolated patches along the course of the Cloncurry River, extending north to Byramine. In central-west, it has reached McKinlay Shire and Winton, in which latter district stringent measures are enforced to keep it in check. Scattered patches occur on the banks of the Warrego, at Cunnamulla, where the officers of the local Lands Department and Council also exercise strict supervision over the district to prevent the spread of the plant. In the southern portion of the State, it is not recorded as extending farther west than the Culgoa River. Between here and the eastern coast, most of the water-courses are burr-infested.

Of the places personally visited during the last six months, the more heavily infested areas are as follows:—

In the North—

Gilbert River and branches.—Between Georgetown and the Telephone Station.
Flinders River and branches—Between Telemon, north-west from Hughenden (north from Julia Creek).

In the Central Districts—

Theresa Creek and branches.—Between Clermont and Emerald.
Springsure Creeks.—Near Vandyck, west from Springsure.
Tower Hill Creek and Cornish Creek.—Near Muttaburra.
Dawson River and branches.—Between Palm Tree and Taroom.

In the Southern Districts—

The Condamine.—Near the Kogan-road and Bridge Warra.
Bungil Creek.—In the vicinity of Roma.
Maranoa River.—Near Mitchell.
Mackentyre River.—Near Goondiwindi.

3. Occurrence in Other States.

Noogoora burr has been known for many years in New South Wales, where it is proclaimed a noxious weed in certain shires and municipalities. It is prevalent along the river banks in the northern parts of the State, especially on the McIntyre, Namoi, Gwydir, and also along parts of the Castlereagh and Macquarie Rivers.

In Victoria, it has not been seen for some years—in fact, not since an isolated outbreak at Dookie was eradicated. It has been recorded from Renmark, in South Australia, and the occurrence of a plant at Bunbury, Western Australia, caused it to be included in the list of noxious weeds of that State.

4. Rate of Spread.

Though Noogoora burr was recognized as a pest in Queensland many years prior to 1890, it is apparently only in the last few years that the extreme seriousness of the infestation, with its grave menace to the sheep industry, has been realized. Prevailing rainfall conditions, more than any other factor, regulate, directly or indirectly, the rate of spread of the burr, and for this reason, together with the annual habit of the plant, it is not possible to state the average annual rate of spread in even approximate figures. Though during spells of drought, the actual size of the annual green crop is relatively small, an enormous quantity of dry burrs is distributed by stock travelling for agistment purposes, while transported fodder may be responsible for the distribution of smaller amounts. Some of these burrs may be deposited in areas which have not previously been affected with the weed, and there they remain until the resumption of climatic conditions favorable to their germination. The breaking of a drought is usually followed by the growth of huge crops with the production of millions of burrs, frequently in places which were hitherto uninfested. The running and rising of rivers and streams, and the return of stock from agistment to such stations as have benefited by the rain, are responsible

for a marked increase in the extent of infested areas, and in the density of infestation during the season subsequent to the termination of the drought.

From almost all parts of the State, reports have been received of marked increases in infestation since 1927, and a few instances of recent spread during the last two or three years are as follows:—

> The burr has been known on the *Flinders River* for 40 years or more, and the increase during the last five years has been extremely rapid. It is reported from *Calliope* that 50 acres are densely infested with burr at present, only one or two plants having been known in the same locality a few years ago. In the *Duaringa* district, during the last two years, it has spread 10 miles along the banks of the creek. In *Springsure,* a property which was thoroughly cleared for £45 five years ago has since become re-infested, and this year the cost of clearing was £200, and it is still not free from burr. The increase in this district appears to have been especially rapid during the last five years. The *Ethridge River* has been infested for some time, but until about five years ago, the infestation was confined, for the most part, to scattered patches. Now, it is so thick and dense in most parts that horses refuse to go through it. About five years ago, it was first noted on the *Gilbert River,* and at the present time there are scores of miles of the banks and islands so densely covered as to be quite impenetrable. The banks of the *Burdekin* in many places, *Augathella, Mirriwinnie* (Cairns district), and *Cloncurry,* have all been reported as recent infestations within the last two or three years, and in the two former of these places, the rate of increase is reported as alarming.

While the majority of the sheep-growers are now alive to the grave danger to the wool industry from the presence and rapid spread of the burr, many of the cattle-owners, who are comparatively little inconvenienced by it, are inclined to treat the matter rather too lightly. But even if it were possible that, through the united efforts of the wool-growers, the whole of the sheep districts in Queensland could be completely freed from burr, this being at such time entirely confined to cattle areas, re-infestation of the cleared country would be inevitable, since the climate and other conditions by which the dispersal of the burrs is affected are, to a large extent, uncontrollable. Consequently, the presence of Noogoora burr in any portion of the State must be regarded as a very serious menace to the wool industry.

5. The Plant.

The plant is an annual, and in both the tropical and subtropical parts of Queensland, germination normally occurs shortly after the spring and summer rains have fallen. Growth at this season is generally rapid, and with the maturing of the burrs during the autumn, the plants wither and die. Each burr normally contains two seeds, one of which usually germinates a season earlier than the other.

A comparatively large quantity of moisture is required for germination, and the majority of the seeds germinate in damp soil which has been recently covered with water, or on the moist beds of waterless rivers or creeks.

From the beginning of March, 1929, until about the 21st, the maximum daily temperature at Goondiwindi was fairly constant at about 85° F. From this time on it began to fall recording 80° F. on 26th March and 71.2° F. on 4th April, and after this germinating seedlings were seen to be less numerous. This indicates that high temperature is also necessary for germination.

Adult plants are regarded as those which have produced normal inflorescences irrespective of their size. Frequently plants growing luxuriantly on the banks of water-courses measure from 2 to 5 feet in height. The height, however, is subject to extreme variations, due mainly to external conditions. Thus adult plants were collected, whose total aerial stem measured less than 1 inch, and others whose stems measured over 13 feet in length.

The normal time of flowering in Southern Queensland appears to be during the end of March and the whole of April. The plant is an extremely prolific one. The following figures have been supplied by a pastoralist in his answers to the questionnaire circulated by the United Graziers Association of Queensland:—"One plant has four main stalks, and each of these has twenty side branches, each branch has approximately from actual count made from one ordinary branch 141 berries, and by this calculation you will see would be 141 x 80= 11,280."

The first ripe burrs were noted (at Goondiwindi) in the second week of April. By the end of May, in all the localities visited, the majority of the burrs were fully ripe and were easily removed from the plants. With the maturing of the burrs, the foliage leaves dry and fall off, but the burrs sometimes persist on the dry standing stems for several years, if situated in a locality which is protected from animals and floods and other extreme conditions of climate.

6. Methods of Control.

(*a*) *Compulsory Clearing.*

Noogoora burr was proclaimed a noxious weed for the whole State of Queensland on 22nd July, 1926. The Prickly Pear Land Commission may enforce the clearing of burr on all leaseholds, and in the event of a tenant failing to clear, after having been notified, the Commission may do so at the expense of the tenant.

In this section reference should be made to the menace of holdings which are neglected owing to the drawing near of the expiration of leases. Some of the most densely infested areas seen were on selections from recently divided large holdings, the lease of which had lately expired.

The clearing of freehold property comes under the direct jurisdiction of the local authorities.

(*b*) *Methods Employed by Graziers and Selectors.*

It is the general opinion among pastoralists that clearing operations can be most effectively carried on during the flowering period. As a rule, by this time, the whole of the season's crop of burr has germinated, and the new burrs are immature. Flowering occurs normally in March and April, during which months heavy falls of rain are of frequent occurrence. Such falls are often followed by the rising of rivers and streams to such a height as to render the burr-infested bank on the opposite side from the homestead inaccessible. The work of clearing on this side of the bank may be hindered in consequence, until

some or all of the plants have brought burrs to maturity. The principal methods of burr clearing in use among pastoralists at the present time are:—

(i) *Handpulling.*—Although expensive, this has been found to be the most thorough method of eradication, especially for scattered plants. In holdings which include vast areas of burr-infested country, the work of destruction must be commenced before the flowering season, otherwise there is danger of some plants ripening their burrs before it has been possible to clear the whole area. Later, the parts in which the work was begun early must be gone over a second time, to ensure the destruction of such plants as have grown since the clearing was done in the first instance. The great difficulty experienced in destruction by handpulling is that of obtaining labourers who are sufficiently careful to look for and pull every plant.

(ii) *Fallen Burrs are Gathered into Sacks and Burnt.*—This appears to be the only satisfactory method known at present for dealing with burrs which have been allowed to ripen and fall. It has been adopted at a few stations, and has proved quite effective in clearing them up if it is carefully done. The price of labour involved in the undertaking, however, is so great as to prohibit the extensive use of the method.

(iii) *Cutting Below Surface of Soil.*—This method is extensively adopted by pastoralists. It has been reported as satisfactory provided the cutting is done during the flowering season, and below the cotyledons.

(iv) *Poisoning.*—This mode of destruction is employed in densely infested areas. In the great majority of cases investigated, arsenic pentoxide solution of strength of ½ to 1 lb. arsenic pentoxide to 1 gallon of water was sprayed on to the plants. Arsenic pentoxide solution has been reported by all those whom I have heard have used it to be 100 per cent. successful in killing burr plants, those which were sprayed with the more dilute solution being as effectively, though more slowly, destroyed.

(v) *Burning.*—In such places as it is safe to burn, this method has been sometimes adopted. It is not possible to burn the plants, however, unless they are growing among thick dry grass, or unless a large amount of dry grass or some other easily combustible material is supplied.

(vi) *Fencing.*—It is the practice of some pastoralists to fence off very heavily-infested areas so that they shall be inaccessible to stock. As a general rule, the area fenced off is on the banks of a water-course. Fencing is effective so far as the individual property is concerned, but, as it does not check the distribution of the burrs by flood waters, it can only be regarded as a temporary expedient.

(c) *Control by Natural Means.*

(i) *Submersion.*—Complete submersion of burr plants growing on the banks of water-courses for two or three days, such as is liable to occur when rivers and creeks rise, causes the death of, or considerable damage to, the submerged plants. It is only a very small proportion of plants which, after prolonged immersion, retain sufficient vitality to produce fresh flowering shoots. Consequently submersion probably accounts for the annual destruction of a considerable number of plants which are growing below flood level.

(ii) *Drought.*—The plants are unable to stand continued and prolonged drought. When drought conditions prevail, the plant appears to make an effort to produce flowers and burrs whatever its size. Thus one plant (growing in a dry area) in which the stem, exclusive of the burrs, measured less than 1 inch, had brought to maturity two apparently healthy normal-sized burrs. The majority of those plants which germinate on stock routes, &c., not in the vicinity of any watercourse do not thrive unless they happen to be growing in a locality of which the average annual rainfall reaches about 24 inches or over, and the season is a normal one. It appears that drought causes the destruction of many burr plants.

(iii) *Frost.*—It has been stated that frost is responsible for the killing of a proportion of exposed seedlings and very young plants.

(d) Biological Control.

(i) *Zoological Means.*—Both cattle and sheep have been observed eating burr plants. This apparently happens more especially at certain stages in the plant's growth, and at certain times of the year. Thus milk cows were seen eating flowering plants in March. During July, I noticed in the south-west of Queensland that the majority of the green burr plants had been nibbled by stock, although there was plenty of dry grass amongst them. One grazier in the Roma district stated that his sheep keep the burr under control by greedily eating the green plant at any stage every year, and no ill-effects of any consequence have been noticed among the sheep. Another pastoralist in the Richmond district reported that his sheep will not touch green burr if any other possible source of food is available. They, however, seem to like dry stacked burr plants, apparently preferring them to dry grass.

Dry fallen burrs were noted in various localities in Queensland, which were empty of seed and had the appearance of having been gnawed by mice or rats. Cockatoos crack the burrs and eat the seeds, and it is alleged that they are often killed thereby.

(ii) *Insects.*—In all those parts of Queensland visited a thorough search was made for insects which might be found attacking Noogoora burr plants. Several insects were collected, most of which were attacking the burrs themselves in one or other stage of the burrs' development. The insects generally pierce the green or dry wall of the burr and feed on the enclosed seeds. Suprisingly few leaves were found which had been damaged by insects, and those which were seen were growing on strong healthy plants, and had only been very slightly nibbled.

As was expected, on account of the Noogoora burr being an introduced plant here, all the insects which were found attacking them were such as do not confine themselves to burr, but also attack other crops and useful plants. For this reason, it would not be economically advisable to breed them in numbers, but this part of the investigation has indicated the possibility of biological control of burr by insects which eat the seeds. It is hoped that success will be attained from a search in the country to which this plant is indigenous, for insects which devour seeds and which confine their attention exclusively to burr.

(iii) *Botanical Means of Control.*—A pastoralist in the Emerald district reports that a coarse grass (*Setaria glauca*) which has established itself on part of the river banks in his property has held the burr plants in check.

Blue Mould of Tobacco: Progress Report of Studies on an Insect Vector.

By (1) *H. R. Angell, Ph.D.*, (2) *A. V. Hill, B.Sc.Agr.*, *and* (3) *G. A. Currie, B.Sc., B.Sc.Agr.*

1. Introduction.

In a previous paper by the senior author (4), evidence was presented to show that one of the suspected, but not previously demonstrated (5), sources of primary infection of tobacco seedlings with blue mould was the material sown. Other more obvious sources of infection of young seedlings (5) are diseased over-wintering or volunteer plants and wild hosts; all of which may produce conidia in spring. Over-wintering and volunteer plants may be easily found on many tobacco farms. It is worthy of note that one of the former was seen last year by two of the writers in a grower's seed-bed. Seedlings which contract the disease from these or other sources of conidia are, instead of being destroyed by the growers, almost invariably allowed to remain, in the hope that they may "recover" and be used later for transplanting. Such seedlings, on which conidia may be found in abundance in spring, constitute a menace to the health of other seedlings in the district, for conidia from them may be carried by the wind, insects, and animals, including man.

In the attempt to find out to what extent such sources of inoculum were responsible for outbreaks of disease, seed from North America was sown in beds on six farms, three near Tumut, New South Wales, and three near Myrtleford, Victoria. All the beds were covered with cheese cloth, were kept well watered, and general conditions were made as far as possible conducive to the initiation and spread of the disease, if and when it appeared. It is sufficient for the purposes of this paper to observe that those beds near to infected plants contracted disease early, whereas those that were further away were affected much later, in one case not until after most of the seedlings had been transplanted. The studies herein reported were undertaken following the observation that in one of the beds in the Tumut area damage by the insect (*Phthorimaea operculella* Z.) and an outbreak of blue mould occurred practically simultaneously.

2. An Insect Vector of the Disease.

On 13th November, one of the beds in the Tumut district was inspected by two of the authors, but no trace of the disease could be found. About 300 of the seedlings were at the same time selected for transplanting in the experimental plots at Canberra. A week later, a few diseased transplants were observed, and it was also noticed that

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(4) Angell, H.R., Blue mould of tobacco: Investigations concerning seed transmission. *Journal of the Council for Scientific and Industrial Research* **2**: 156–160 (1929).
(5) Adam, D. B., The blue mould (*Peronospora*) disease of tobacco. *Journal of the Department of Agriculture of Victoria*, **23**: 436–440, (1925).

the split worm* *Phthorimaea operculella* Z. was attacking some of them. Inquiry was thereupon made concerning the remaining seedlings, and it was then learned that both the insect and the disease were present in the beds from which they had been taken. It was evident that both had been brought to the Canberra plots with the seedlings. Furthermore, as the seed-beds in Tumut were some 2 miles away from the nearest diseased plants, the insects were suspected as being probably responsible for the transportation of the inoculum. There is also the possibility of its having been air-borne or transmitted by other agencies, including man. Experiments to determine the number of conidia in given volumes of air in and at varying distances from seed beds are soon to be undertaken.

3. Examination of Moths from Infected Plants.

To determine whether or not moths may carry the conidia of the blue mould fungus, seedlings in beds in the experiment plots at Canberra were artificially inoculated and the disease allowed to spread. Moths from the surrounding plants had been previously noticed attacking the seedlings. On March 1, at 5 a.m., twenty of them were collected from the beds. This was done by placing an 18 in. x 18 in. x 18 in. organdie-covered cage over selected portions of the bed, and transferring the moths that flew up into it to a glass tube. In this tube they were taken to the laboratory, transferred to a test tube to which were later added a few centimeters of water, the contents of the tube shaken, after which drops of the suspension were placed on slides and examined under the microscope. Six slides were examined and three to ten conidia were counted in each drop, the average being six conidia per drop. On this basis the total number in the suspension was 300, an average of fifteen conidia per moth. It should be noted that at the time of collection of the moths, the conidia present on the infected seedlings were few in comparison with the number normally present on seedlings in spring. This was apparently due to the low humidity and hot weather prevailing in Canberra at the time.

In order to ascertain the approximate number of conidia that may be carried by moths under optimal conditions, four moths from a plot of healthy plants were introduced into a glass tube in which had been placed a tobacco seedling on which there was a blue mould lesion sporulating freely. After being allowed to remain for two to three minutes they were removed to another tube, each rinsed with a few cubic centimeters of water, and drops of the suspension examined. The number of conidia on each varied between the limits of 600-4,000. Another moth that was observed to alight four times on the lesion was was found to carry over 1,000 conidia, and another that alighted only once carried with it over 60. The diseased material was removed from the vessel, and moths obtained from healthy plants were admitted. The vessel was shaken, the moths removed, washed with water, and the suspension found to contain on the average 300 conidia per moth. Moths collected at the same time from the same plot (in which no blue mould was present) were found to be free of conidia.

* This insect is probably better known in Australia as the potato tuber moth, formerly known as *Lita Solanella* Boisd.

4. Infection of Seedlings by Moth-carried Conidia.

On 10th March moths were collected in the field, and transferred to a 4-in. x 1-in. specimen tube containing a tobacco seedling with fresh blue mould lesions bearing conidia. They were left in this tube for ten to fifteen minutes and then allowed to crawl or fly into a spore-free vessel. In the latter the moths were taken to a room in which there were no plants infected with blue mould, and they were then admitted at intervals to tobacco seedlings grown from clean Canadian seed on sterilized soil in Petri dishes. The seedlings used had germinated five to seven days before the experiment was carried out, and averaged about 600 per dish.

As will be seen by the accompanying Table, four to seven moths were admitted to each Petri dish at intervals ranging from one minute to two hours after removal from the tube containing the infected material. An equal number of controls was kept, and all of them remained healthy.

In contrast, it will be seen that on examination on 14th and 15th March, several seedlings in the Petri dishes into which moths had been admitted were showing the characteristic conidiophores and conidia of the blue mould fungus. No more infected seedlings were observed during the succeeding seven days, after which they were discarded. It should be noted that the usual period of seven days required for infection was in this case, as well as in others that have come under our notice, reduced to four days, this being apparently due to the very favorable conditions of temperature (23° C.) and humidity under which the seedlings were kept, and more especially perhaps to their extreme susceptibility at that age.

TABLE 1.

Infection resulting from introducing moths bearing conidia into Petri dishes containing tobaccc seedlings.

Number of Dishes into which Moths were Introduced.	Time after Removal from Diseased Material.	Number of Moths used in each Dish.	Number of Seedlings showing Blue Mould.		Controls.*	
			After Four Days.	After Five Days.	Number of Dishes.	Condition after Five Days.
1 ..	1 minute	5	5	25	1	Healthy
1 ..	1 „	5	8	50	1	„
1 ..	1 „	7	18	75	1	„
1 ..	15 „	4	1	10	1	„
1 ..	15 „	4	1	9	1	„
1 ..	30 „	4	2	14	1	„
1 ..	30 „	4	1	2	1	„
1 ..	1 hour	6	1	9	1	„
1 ..	1 „	4	1	5	1	„
1 ..	2 „	7	6	15	1	„
1 .. (No moths)	Sprayed with conidia		100% infection			

* These control dishes were planted with seed from the same lot as used in the insect series in order to demonstrate that the infection counts in Column 4 did not originate as a result of seed-borne disease.

5. Discussion.

From observation in the field and by glass-house experiments, it has been found that the sources of primary infection of tobacco seed-beds may be diseased overwintering or volunteer plants, wild hosts, and diseased seed. From these initial sources conidia are carried to healthy seed-beds in the neighbourhood either by the wind or by insects, or both.

In seed-bed tests in 1929, infection and moth injury to the seedlings in one bed appeared simultaneously. It is therefore likely that the conidia of the blue mould fungus were carried by the insects. There is also the possibility that they were transported by air or other agencies.

In this progress report, evidence is presented to show that moths of the tobacco split worm *Phthorimaea operculella* Z. collected from diseased seed-beds carry the conidia of the blue mould fungus mechanically. Futhermore, laboratory experiments indicate that when moths carrying conidia are allowed to alight on healthy seedlings, infection results if the conditions are favorable. As we have found that moths may live and fly for over a week, and that under certain conditions of temperature and humidity the detached conidia of the blue mould fungus may remain viable for, and germinate* after 54 hours or more, we are inclined to think that the insect may be responsible for transporting inoculum from diseased overwintering plants and seedlings to others that are healthy, and that provided conditions of temperature and humidity are favorable, infection results.

The evidence so far gathered seems to be conclusive and so important in devising methods of control, that, despite the fact that the work is just begun, we feel justified in publishing these findings.

It follows that other insects attacking, or even visiting seedlings, may also be possible carriers of conidia.

6. Summary.

(1) The moths of the tobacco split worm *Phthorimaea operculella* Z. collected from diseased tobacco seedlings carry the conidia of the fungus causing blue mould of tobacco.

(2) Other moths of the same species that were allowed to come in contact with diseased material caused healthy seedlings on which they later alighted to develop characteristic symptoms of blue mould. An equal number of checks remained healthy.

(3) It is suggested that they, as well as other insects, may be responsible in some instances for transferring conidia from diseased plants to healthy seed-beds in the vicinity.

* Unpublished work.

Radio Research.*

PAPER No. 1.

Fading.†

By A. L. Green, M.Sc.

1. Introduction.

"Fading" is the popular name for a phenomenon which must be well known to anyone who has tried to listen to interstate broadcasting. For instance, the Melbourne station, 3LO, can be heard in Sydney in the evening, but every twenty minutes or so the signal fades right away, so that apart from the fascination of long-distance reception, there can be very little pleasure in it purely from the entertainment stand-point.

Fading, too, is a big problem in commercial radio, where reliable communication over long distances has been the aim of radio men from the earliest days. It is true that we can send radio messages almost as far as we please, but until now this has meant, in practice, the erection of transmitters of enormous power. In their endeavours to reach round the world, radio men have had to work on the assumption that one has to shout in order to be heard, but now that wireless telephony has been proved a possibility, even between Australia and England, the time has come to look much more closely into the mechanism of long-distance communication, the reasons being two-fold. Firstly, if we could find out just how radio waves travel round the world, it is reasonable to suppose that we could then build a transmitter to make the best use of our knowledge, with a consequent increase in efficiency and reduction of expenditure. Secondly, the design of receivers, and receiving aerials in particular, ought to take into account the nature of the wireless signals that are being received. At present receiving aerials pick up every electrical disturbance, and it is left to the receiving set to pick out from this jumble what we wish to listen to.

2. Long-distance Reception.

The transmission of wireless signals over great distances is now so commonplace that one rarely stops to think why it is even possible. Before Marconi demonstrated his trans-Atlantic transmissions, it was thought to be impossible to send radio signals over distances greater than a few miles, and that for a very good reason.

Let us take, for example, the case of a transmitting aerial on a ship where the tops of the mast might be some 80 feet above the water-line. A nautical man would tell you that the mast could just be seen by a man some 10 miles from the ship. If, however, the observer was in the crow's-nest of another boat, the distance would be nearer 20 miles. Now this can be applied directly to the radio problem, since the receiving aerial would be at about the same height as the crow's-nest, and since wireless waves travel exactly in the same way as light, that is to say, in straight lines, we should expect radio to be

* The two authors of these papers are officers of the Radio Research Board of the Council, towards the cost of which the Postmaster-General's Department is contributing half the necessary funds. By kind permission of the authorities concerned they are located in the P. N. Russell School of Engineering of the University of Sydney.

† Based on a recent broadcast address.

effective over the 20 miles separating the ships. Directly a ship sails over the horizon, it is lost to sight, and it ought to be lost as regards radio, too. Unfortunately, from the point of view of the theory, we can still communicate with the ship by wireless at distances running into thousands of miles. At this point we begin to wonder just how and where the signals travel, and granted that we still believe that radio waves are propagated in a straight line, we are forced to the conclusion that the waves must go through the earth. This is easiest seen if we take the extreme case of communication between Australia and England.

There have been investigations of wireless propagation through the earth, where a receiving set has been taken to the depths of a coal mine, and the results showed that although signals were audible, they were extremely weak in intensity. This would be at a depth of only a few thousand feet, so that we could not reasonably hope to signal through 8,000 miles of earth, as we should have to between Australia and England. At this stage, we are indebted to the English mathematician, Oliver Heaviside, who first suggested a way out of the difficulty. He said that if the waves could not go in a straight line through the earth, and since they certainly could not bend right round the earth, travelling over its circumference, the only other possibility was this: The signals from a transmitter must climb into the air, getting progressively higher in the atmosphere as the distance from the transmitter increased. For instance at 100 miles from the transmitter the waves would be 2 miles above our heads, and we should theoretically be compelled to use an aerial of this height to receive them. The supposition then is that the signals continue to travel outwards and upwards in a straight line until they meet a region of electrified gas now called the Heaviside layer, at which they are bent downwards, subsequently striking the earth again at a point some hundreds of miles from the transmitter. The Heaviside layer acts towards wireless signals in much the same way as a mirror reflects light. With the mirror we can see round corners, and by means of the peculiar properties of the Heaviside layer we can signal round the earth without going through it.

3. The Heaviside Layer.

The Heaviside layer hypothesis is therefore capable of explaining the experimental fact of long-distance transmission, and we conclude that the best way to send a signal to a distant receiver is to project the wireless wave into the air, hoping that the Heaviside layer will turn it down again towards the earth. Any calculations on the matter, however, are indefinitely held up until we can answer the question as to whether there is a Heaviside layer, and if there is, what is its composition, its height, and its reflecting power? From investigations that have been made already in England, it seems that the Heaviside layer is at least 50 miles above the surface of the earth. The only possible method of attacking the problem, therefore, is the indirect one of sending up a wireless signal to the layer and then, when it has come to earth again, to receive it with apparatus that will extract from the signal the story of its travels.

Now, the best way to investigate the properties of a signal which has been returned from the upper atmosphere is to compare it with some standard signal about which we do know something.

The Ground Signal.

The only standard signal that we have available is the one that has travelled along the ground to us from the transmitter. This ground signal has travelled over a certain measurable distance, and if necessary we can easily investigate its journey simply by taking numbers of measurements with a portable receiver at convenient intervals along the path of propagation. We can see at once that, according to the simple theory previously outlined, the ground wave should die out at quite a moderate distance from the transmitter, of the order 20 to 50 miles, according to the height of the transmitting aerial above the earth's surface, so that there should be large areas where there is no ground wave available as a standard with which to compare our sky signal. Every-day experience teaches us, however, that it is quite easy to receive a ground wave when the transmitting aerial is out of sight; otherwise any tall building would produce a blind-spot behind it. To explain this very elementary point, we only need to remember the principle of refraction. A glass prism is capable of refracting or bending a beam of light, and, in the rainbow colours produced by this simple form of spectroscope we have a proof that some varieties of light are bent or refracted more than others. In just the same way, the air at the surface of the earth bends wireless waves, and it is a matter for congratulation that they happen to be refracted towards the earth, instead of being bent upwards and away from it. As in the case of light, so with wireless, some waves are bent more than others, and although very long waves may be refracted round a quarter of the earth's circumference, the medium wave lengths will normally die out about 100 miles from the transmitter.

Field-Strength Measurements.

The justification for the last statement is in measurements that have been taken of field-strengths around a broadcasting station. The method of doing this depends only on having a portable receiver connected to a small loop aerial, and noting the strength of the wireless transmitted at any given spot. Elaborate gear has to be used to ensure that the efficiency of the receiving set is constant, whatever its location, but the main principle is simply that of having a portable receiver which will always give the same reading at a given place, and which will also give a comparison between the field-strengths at different places. The term field-strength means the strength of the electric field of force which is being taken. Some work has been done already in Australia by Radio Research Board workers with field-intensity sets, and valuable information has been obtained as to the differences between transmission over land and sea, and over different varieties of land. Briefly, it has been shown that the ground wave travels best oversea; for instance, the shortest path between Sydney and Jervis Bay is almost entirely marine, and it was found that the ground wave arrived there in much better condition than it did at Newcastle after having travelled over a much more exacting course. A comparison with conditions in hilly and thickly-wooded Sydney shows that Melbourne listeners are entertained by a much more healthy ground wave. In Sydney the wave spends a lot of its energy climbing up the surrounding hills and through the woods, finally arriving in very poor condition. However, we must remember that, so long as a wireless wave keeps to the ground, it is possible for an observer to follow it up and to specify it at the end of the journey.

Sky Waves.

The sky wave is much more elusive. There is some evidence for supposing that some of the short waves have travelled at least twice round the earth before being finally turned earthwards by the Heaviside layer. Others have been known to take a journey out beyond the moon, and to come back after the comparatively long interval for a wireless wanderer of some 10 to 15 seconds. These echoes of long delay are still a great mystery to us, since we are driven to the conclusion that parts of the Heaviside layer are transparent. That they only appear to be so in the northern hemisphere, in the months of October and March, is a greater mystery. These two instances of the vagaries of the sky wave are almost sufficient in themselves to justify an investigation of the properties of the Heaviside layer, but we can add much more weighty arguments.

What of the listener stationed more than 100 miles from the nearest broadcaster? He has NO steady ground wave to listen to, and is dependent entirely on the whims of the sky wave, coming from the fickle upper atmosphere. During the day-time, when the intense power of the sun saps all the energy out of the sky wave, he can hear nothing; and at night, when sky waves can get through at all, they come more than one at a time. Sometimes they pull together, and sometimes they neutralize each other's efforts, so that the distant listener's reception is, even at night-time, a variable quantity.

Now, let us consider the case of the listener at an intermediate distance, where the ground wave is rather feeble. During the day he will get steady reception, though rather weak in intensity, but at night the ground wave will suffer interference from the sky wave, which makes its appearance directly after sunset. The result of this, of course, is "fading"; that is to say, the effect of interference between a ground wave and a sky wave. Obviously, the problem which we must solve is that of making these two waves pull together, so that the net result then would be a steady increase of signal when the sky wave appears, instead of an increase at one moment when they work in harmony, and a diminution the next, when they are in opposition. We have no quarrel whatever with the ground wave, since it is steady; it is the uncontrollable sky wave that causes the fading. At greater distances, of course, we are dependent entirely on the variable sky wave, so that until we learn how to harness it, we shall never get really reliable long-distance reception.

Heaviside Layer.

And this brings us to the consideration of the Heaviside layer, since if it were not for this gigantic electrical mirror above us, the sky wave would never come down to us again. The composition of the layer must be an electrified gas, since experiments which can be done in a laboratory prove that such a gas can bend wireless waves; the only other reflector which we know of is a sheet of metal, and quite obviously that cannot be the constitution of the Heaviside layer. As to how dense this electrified gas is, we only know within certain limits, and that from an investigation of sky waves that have been affected by it. It is fairly easy to see that very short waves have a chance of slipping through the layer if it is not too densely packed, while long waves would rebound from it.

Now, those waves which have already been mentioned as having journeyed out past the moon must have passed through the layer twice, if they are to get back to earth again, and until now, these echoes of long delay have all occurred with short waves about 30 metres long. We can thus calculate from the length of those waves which penetrate the layer the probable density of it. These measurements have been made in England, but so far an opportunity has not occurred in Australia. It is interesting to notice here that communication with the planet Mars must be attempted, if at all, with the very short waves, since a longer wave could never pierce the earth's atmosphere. There is, too, the possibility that Mars has a Heaviside layer of its own, and naturally we have no information as to what length of wave could get through it.

Another property of the Heaviside layer which is susceptible to measurement is its height, and this is a very important quantity, since the path of the sky wave is the longer, the higher the layer. Further, if this height varies, the sky wave must vary too, and we are trying to solve the problem of the variable sky wave, so that we must know just how far the sky wave has to travel before it can be sent down to us again. Measurements of the height of the layer are carried out in two ways, the simplest of them relying on the echo principle. Suppose a transmitter is switched on for a very short period, less than a second, and as suddenly shut down again. A signal is sent along the ground and recorded at a receiving station, say, 50 miles away. At the same time as the ground signal leaves the transmitter, another travels up to the Heaviside layer, is reflected, and comes down to earth again at the receiver, where it is recorded photographically on the same film as the ground signal, but a little while after it. Now, we know the speed of the wireless wave, and we can measure the echo time from the photograph, so that it is simply a matter of calculation to find out how much further the sky wave has travelled than the ground wave. The sky wave has traversed two sides of a triangle of which the ground is the base, so that the height of the layer corresponds to the altitude of the triangle, and this is easily calculated, as we know the lengths of the sides of the triangle.

Value of Work to Australia.

So much for the problem of the Heaviside layer, which has such an important influence on sky waves, and therefore on all long-distance reception. However, there is just one more question which needs an answer. Granting the importance of research in connexion with the Heaviside layer, is it not true that investigations have been made in England for the past five years? Why, then, should Australia bother with a problem which is in such good hands? The answer to that is in the different conditions which we have in Australia of time and place. So far, Heaviside layer measurements have only been made in the northern hemisphere, and under vastly different climatic conditions. In England at the present time sunset is in the afternoon; in three months' time it will be more nearly nine o'clock in the evening. In England the sun is never strong enough to produce that complete paralysation of the sky wave on a summer's day. In England no listener is more than 50 miles from a broadcasting station, and the problem of supplying the distant settler with news and entertainment does not arise.

From the scientific point of view, too, there is every reason to suppose that the earth's magnetic field has a profound influence on sky waves, so that we should expect the Heaviside layer to act quite differently in the southern hemisphere, that is, in Australia. And we must know about the Australian Heaviside layer if we are to communicate with the rest of the world efficiently, since transmission and reception over very long distances depend on the Heaviside layer, both here where we send, and there where the message is received. Lastly, we must remember that Australia, due to its enormous area, is for all practical purposes the southern hemisphere. If, therefore, the problem is not tackled in Australia, it never will be on this side of the equator.

PAPER No. 2.

Atmospherics.*

By L. G. H. Huxley, M.A., D.Phil.

1. Introduction.

As I propose to give a short account of some recent investigations on the nature of atmospherics, it will be as well to explain at the outset what is meant by the term "atmospheric."

Like a number of other unpleasant things, an atmospheric has a variety of names, being known also as an "X, stray, or static," nor have I any doubt that every listener has at times applied names to it scarcely fitting for me to broadcast on a Sunday evening.

Atmospherics are the naturally occurring electric waves which reveal themselves in no uncertain manner by their interference with more legitimate signals in your receivers. I employ the term "atmospheric" generally used in England, in preference to the American word "static," since in the first place it gives an indication of the origin of the disturbance, and, secondly, the word "static" is scarcely descriptive of the resulting cracks and bangs which so rudely interrupt your reception.

It would not be unreasonable to suppose that atmospherics, like other pests, should be studied with one object alone, namely, their elimination, and, indeed, for many years attempts have been made to rid wireless reception of this trouble, but without real success. It occurred, however, to a physicist in England, Mr. Watson Watt, that the more sensible course was to compromise with the enemy by making the atmospheric itself, rather than its elimination, the object of study. It might appear at first that very little was to be gained from this method of approach, but the results almost justify the application to atmospherics of Mr. Belloc's lines about the frog, where he says—

"No animal will more repay
A treatment kind and fair."

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* Copy of a recent broadcast address.

2. Investigations in Great Britain.

In collaboration with Mr. Herd, and under the auspices of the Radio Research Board of Great Britain, Mr. Watson Watt began a series of investigations whose object was to provide answers to questions such as the following:—

(1) What is the nature of an atmospheric?
(2) From what direction does it come?
(3) How far has it travelled?
(4) Have atmospherics any connexion with the weather, and in particular with thunderstorms?
(5) How do atmospherics arise?
(6) For which wave lengths do they cause greatest interference?

I shall deal briefly with the information accumulated on these points.

(1) *What is the nature of an atmospheric?*

It is clear that the atmospheric is some type of electric wave which on arrival at the aerial causes a current to flow that is ultimately translated into the crash heard in the loud speaker.

In order to determine the structure of this wave, a special receiver was constructed which permitted an actual visual observation to be made of the variation of the electric field in the wave. As was to be expected, it was found that the atmospheric differed greatly in nature from the ordinary broadcast wave, such as the one which excites your sets at this moment. Whereas the latter sustains a current in your aerials oscillating to and from indefinitely at an essentially regular rate of the order of a mere million times a second, the atmospheric applies a force to the aerial many thousand times as strong, but lasting only a few thousandths of a second. As a rough analogy, one may compare the soft sustained note of a flute and the loud crack of a whip.

Though of such short duration, atmospherics themselves are by no means of identical structure. Some consist of a single oscillation to and from of the electric force, others merely of half an oscillation, while others contain several oscillations rapidly dying away. Still others are of the above types with more rapid oscillations superimposed.

(2) *From what direction does it come?*

One of the first essentials in studying atmospherics is to be able to determine at any place the direction along which atmospherics are arriving. Two types of instrument were constructed to achieve this. In one type, a continuous record is made on a rotation drum of the average directions of arrival of various streams of atmospherics. In the other, the direction of arrival of individual atmospherics can be read off from the movement of a spot of light across a graduated transparent compass dial. This latter instrument is called a "cathode ray direction finder." The ordinary direction finders, such as are used in navigation, are useless for determining the direction of atmospherics, because they can be used only with sustained signals, whereas the cathode ray direction finder can deal with signals, such as atmospherics, lasting only a few thousandths of a second, while at the same time indicating their strengths. The cathode ray direction finder will also

give admirably the direction of sustained signals. My colleague, Mr. G. H. Munro (now at Melbourne), and I conducted a series of experiments at sea with it, and were able to obtain accurate bearings on stations as far apart as England, Madagascar, Japan, and Java. Using a single instrument of the first type mentioned above, it is found that streams of atmospherics arrive throughout the day whose intensities and directions vary regularly with the time of day and season. In addition to these regular streams, casual streams are generally to be found.

(3) *How far have they travelled?*

Our next problem is to locate on the map the sources of these atmospherics. To do this, two observers, each with a direction finder, are stationed a known distance apart (e.g., at Sydney and at Melbourne). The atmospheric wave when emitted from its source travels with enormous speed—an aeroplane at the same speed would fly round the equator seven times in a second. The atmospheric therefore is recorded on the two direction finders almost simultaneously. The observers, who are in telephonic communication, ascertain that they have noted the same atmospheric and record its direction of arrival with their respective instruments. The two directions will in general be different, and from them, by simple geometrical construction, the source of the atmospheric can be located on the map. In this way it is possible to locate any number of sources of atmospheric activity at a given time.

It was revealed that atmospherics were not necessarily of local origin, as many people believed, but that they could effectively interfere with reception even after having travelled 4,000 miles. It was interesting to find that Russia was a source of atmospheric for England.

(4) *Can atmospherics be correlated with meteorological phenomena?*

Analysis of the results obtained with instruments situated in the south of England, the north of Scotland, Germany, and Egypt showed that very definite correlations could be obtained. In one analysis of some 500 located sources, at least 87 per cent. were found to agree closely in position either with actual thunderstorms or with reported unsettled weather conditions.

There is one meteorological condition which was always found to yield a plentiful supply of atmospherics. This is a certain region in a cyclone known technically as a "cold front." The passage of such a front was traced by Mr. Herd, using two direction finders, for some 1,800 miles across northern Europe. It is evident that we have here a very powerful tool for weather forecasting.

The question still remains as to the origin of atmospherics. It has always been suspected that atmospherics are closely connected with thunderstorms, and as already mentioned, their location frequently coincided with reported thunderstorms. Further interesting confirmation was given by Professor Appleton, and Messrs. Watson Watt and Herd, who showed that the actual strength and structure of a typical atmospheric were those to be expected from a lightning discharge. They were even able on these lines to estimate the amount of electricity transported in the lightning flash, and found good agreement with the values obtained in a totally different manner.

Thus, atmospherics are considered to arise in electric discharges, whether visible as lightning or not. In the "cold front" of a cyclone, violent uprushing currents of air occur, and such a condition is favorable to the production of electrical discharges such as lightning, so that it is not surprising to find that "cold fronts" are fruitful sources of atmospherics.

It may seem incredible that the vast number of atmospherics reaching our receivers could all arise in electrical discharges, but if one realizes that at any moment there are on the average throughout the whole world 1,800 thunderstorms in progress, and that lightning flashes occur at the rate of 100 per second, while an atmospheric may have a range of 4,000 miles, it is less surprising.

Since the tropics are the great thunderstorm regions, tropical and sub-tropical countries, such as Australia, suffer most from atmospheric interference. As far as their interferent properties are concerned, it is found that atmospherics are most troublesome for the longer wave lengths, but this matter awaits further investigation.

3. Investigations in Australia.

It remains to point out the particular value of research on atmospherics in Australia.

For accurate weather prediction, it is essential to have a great number and wide distribution of meteorological stations. Europe, with its large populations, is fortunate in this respect, but even there the location of atmospheric sources has been proved a most valuable source of information.

In Australia, on the other hand, meteorological stations are confined to the coastal regions, while the wastes of the interior yield little or no data.

It is proposed to establish atmospheric observing centres at Watheroo in Western Australia, where the work is already in progress, and at the Observatory of Mt. Stromlo, near Canberra, thus forming a huge base line from which the central regions of the continent may be kept under observation. In this way it will be possible to provide information about the weather to the man "out-back," which is now not possible, and at the same time to procure data for weather forecasting in general.

A novel use has been made of atmospherics in Canada, where it was noticed that the atmosphere over forest fires was frequently a source of atmospherics. This is due probably to the uprushing currents of air, which, as we say, seem to be necessary for discharge phenomena. By means of direction finders it was possible to give warning of the progress of the fire.

There are in addition problems which are most readily approached under Australian conditions, and my colleague, Mr. Munro, and I hope to obtain valuable results.

In view of the large amount of information which has been accumulated in Europe on atmospherics, it might appear superfluous to pursue similar work in Australia. This, however, is by no means

the case. It would not be expected that conditions in the southern hemisphere are exactly those in the northern, since, for instance, the distribution of land is quite different.

We intend, as a start, to work along the following lines:—

(i) To track down the main permanent sources of atmospheric interference in Australia;

(ii) to note their daily and seasonal variations; and

(iii) to determine the wave lengths for which they cause greatest interference.

In this way we hope to acquire accurate information of value to commercial telegraphy.

We are fortunate in beginning our work with new tools, for there is still much to elucidate, both of commercial and scientific interest, and we shall develop our instruments as new problems arise.

Before attempting to eliminate atmospheric interference an accurate local knowledge of atmospherics must be acquired, but even then it is doubtful whether it is possible to do more than avoid them after having tracked them to their lairs.

I trust that, although I have given you scant encouragement on the question of their elimination, yet I have succeeded in showing that atmospherics themselves form interesting and valuable objects of study.

In conclusion, I wish to say that the work is being carried out on behalf of the Radio Research Board for the Council for Scientific and Industrial Research.

The effect of a "Soil Mulch" on the Quantity of Water Lost from a Given Soil by Evaporation.

By E. S. West, B.Sc., M.S., Officer in Charge, Commonwealth Research Station, Griffith.

1. Introduction.

The opinion was very generally held at one time that the presence of a loose soil "mulch" appreciably reduced the evaporation of water from the soil into the air above. This contention has from time to time been questioned.

Thus Lyon, Fippin, and Buckman (1), in their textbook on soils, indicate that soil mulches retard evaporation from the soil; while in a later publication by two of these authors (2) the opinion is expressed that a soil mulch is not very effective in this connexion, but that as far as soil moisture control is concerned, the importance of cultivation lies in weed destruction.*

Several investigators, particularly in the United States of America, deny that soil mulches have any appreciable effect on moisture conservation, the work of Veihmeyer (3) perhaps being the best controlled and most convincing.

It is possible that conclusions reached early in the century, largely from theoretical considerations, were accepted without sufficient experimental verification. The capillary movement of water through a loose "mulch" compared with a compact soil was thought greatly to reduce evaporation from the soil under the mulch; but it is now generally considered that capillary movement through the soil is very limited, and is mainly of importance in supplying water to the plants from soil in the immediate vicinity of the root hairs (4).

It is an established fact under Australian conditions that bare fallowing under certain conditions leads to increased wheat yields. This has often been attributed almost exclusively to the effect of the mulch in moisture conservation Obviously, many other factors may be of importance, such as the physical condition of the soil, resulting from the fallow, or chemical or bacteriological effects of the fallow.

It is possible, of course, that widely different effects may be observable on different soil types; nevertheless, it was thought that any information on the subject from any particular soil type would be of value in confirming, or otherwise, conclusions reached by other investigators on other soil types. Conclusions reached in the laboratory, or from more or less artificial soil profiles, such as in tank experiments, require to be finally tested out in the field, and for this reason an experiment to determine the effect of a soil mulch acting under field conditions was carried out on a local soil, that of the Commonwealth Research Station, Murrumbidgee Irrigation Area, Griffith, New South Wales.

* A similar change of opinion apparently occurs in the 1916 and 1926 editions of Fortier's "Use of Water in Irrigation"—McGraw-Hill Book Co.

2. Description of Soil Profile.

This soil has a mature profile of sharply defined horizons.

The surface soil, to a depth of 23 cms., is a brownish-red sandy loam. A band of dark reddish-brown clay occurs from 23-43 cms. The line of demarcation between the surface soil and this clay band is very sharp; however, a close examination reveals that the upper limit of the clay is not perfectly flat, but small undulations or "bumps" occur about 1 cm. high, so that on a face the junction is represented by an undulating rather than a straight line. This made sampling difficult, as small amounts of the clay-band in the surface soil, or vice versa, would lead to serious errors in the moisture determinations. Immediately above the clay-band, a small "hardpan" 3 cms. thick occurs. It is not very well developed on this particular profile, and is so similar to the rest of the surface soil that it has been included in the samples 10-23 cms. It consists of a small percentage of highly dispersed colloidal material in the soil that would otherwise be similar to the rest of the surface soil.

Below 43 cms. the soil is enriched with lime, and limestone concretions occur in the form of vertical columns about 3-5 cms. in diameter. These limestone concretions are very numerous almost to the depth of sampling in this experiment (213 cms.), and amount to as much as 17 per cent. of the weight of the soil. They made sampling very difficult at this depth, and, as discussed later, considerably increased the error of sampling. They were avoided as far as possible when taking the samples.

3. Plan of Experiment.

The experiment consisted essentially in irrigating a number of plots with sufficient water to soak to a depth of at least 6 feet, after which half of the plots were dug to a depth of 10 cms., and the soil mulch so formed was maintained until the completion of the experiment. After a period of about four weeks some of the plots were sampled, and the moisture content of the samples determined, and a comparison was made between the moisture content of the soil in the mulched plots with those not mulched. Other plots were sampled, and a similar comparison made, after a period of about five months had elapsed. During the course of the experiment the plots were covered during rain, and no water was applied in any form, and no vegetative growth was permitted.

The chief difficulty to be overcome in an experiment such as this is the large variation in soil texture usually present. To overcome this as far as practicable, 24 plots, each 2 feet square, were used, arranged in six rows of four. The use of plots of this size enabled the experiment to be confined to quite a small space, thus lessening the chances of soil variation. On this soil, small patches of obviously different texture occur in places from which the native trees have been grubbed. By confining the experiment to a small space, such areas could be avoided, and it was also easy to cover the experiment when rain occurred. The soil was examined on all sides of the selected site to a depth of 12 feet with an auger, which indicated that no sign of a water-table existed at that depth, but that, on the contrary, the soil was almost dry.

In order to isolate each plot from its neighbours, trenches 7 ft. 10 in. deep and 2 inches wide were excavated on the boundaries and in between the plots; into these trenches 8-ft. lengths of galvanized corrugated iron were introduced, 2 inches projecting above the surface. The iron was lapped at least two corrugations at joins and at the corners. Soil was back filled and rammed in the order in which it was taken out. When completed, each plot was therefore isolated from its neighbour by galvanized iron, which prevented any movement of moisture from one plot to the next; but the soil was disturbed a distance of only 1 inch from the iron.

The plots were then irrigated through a fine rose, the quantity of water applied to each plot being measured out. The 2 inches of iron projecting above the surface at the boundaries of the plots simplified the addition of water to individual plots, and no water could pass from one plot to another. In all, a depth of 12 inches of water was applied, and trials carried out on neighbouring soil showed that this amount of water would moisten the soil to a depth of at least 6 feet within seven days. During the irrigation, water was also applied to the soil around the experiment in approximately the same quantity.

As soon as it was in a suitable condition, the surfaces of alternate plots (chessboard fashion) were dug to a depth of 10 cms., due care being taken that exactly this depth of soil was disturbed. A fine mellow mulch resulted. As soon as this was done, the top 4 inches of the iron partition, i.e., to a depth of 2 inches below the surface, were cut away, and small "pug" walls, made of well-kneaded surface soil, were substituted. These walls dried out sufficiently hard to be durable, but did not crack. The object of the walls was to minimize as much as possible the conduction of heat downward by the iron.

A galvanized iron roof mounted on small wheels running on concrete runways enabled the plots to be quickly covered when desired, and the plots were protected from all rains, but otherwise were left exposed.

In sampling the plots, a trench 8 feet deep was dug along one end adjacent to the end row of plots, and the iron was removed from the border of one plot. The soil was removed from the face to the centre of the plot, and the sample pared off from the face at the centre of the plot, and introduced directly into a honey tin, and the lid was pressed on. From 500-700 grammes of soil were taken for a sample. Owing to the heterogeneous nature of the zone of lime accumulation, a sample of this size would seem to give better results than a smaller sample. In sampling in this zone, the limestone pipes were avoided as far as possible, but, even so, the samples were necessarily from a rather heterogeneous material.

Two samples were taken at each depth, the depths selected being determined mainly by the soil profile, and were as follows:—0-10 cms., depth of mulch on cultivated plots; 10-23 cms., depth of surface soil; 23-43 cms., clay band; 43-63 cms., zone limestone accumulation; 63-93 cms., zone limestone accumulation; 93-133 cms., zone limestone accumulation; 133-173 cms., zone limestone accumulation; and 173-213 cms., zone limestone accumulation. It is to be noted that samples were taken at more frequent intervals near the surface than at a greater depth, as it was anticipated that any differences noted would be greater near the surface, where the moisture gradient would also be greatest.

The iron partitions extended about 2 feet below the depth of sampling; the reason for this precaution is, of course, obvious.

4. Moisture Data.

The cultivated plots were mulched on 19th November, 1928, and one-half of the experiment (i.e., six mulched and six not-mulched plots) were taken down 19th December, 1928 ; that is, after a period of 30 days. The remaining plots were sampled 1st May, 1929, a period of 23 weeks after mulching.

TABLE I.

Moisture Data for Samples at 23-43 cms.

	First Sampling, 19th December, 1928.				Second Sampling, 1st May, 1929.			
	Plots.	Moisture Content.	Sticky Point.	Corrected Moisture Content.	Plots.	Moisture Content.	Sticky Point.	Corrected Moisture Content.
Mulched plots.	1 ..	26.6	28.5	25.8	14 ..	23·7	26·15	25·25
		24.2	26.0	25.9		25·1	28·45	24·35
	3 ..	28.1	29.5	26.3	16 ..	24·1	27·3	24·5
		29.1	30.6	26.2		24·2	27·4	24·5
	6 ..	25·7	27·3	26·1	17 ..	24·9	28·45	24·15
		26·1	28·4	25·4		24·3	28·55	23·45
	8 ..	26·0	27·5	26·2	19 ..	27·0	31·2	23·5
		23·8	24·35	27·15		25·6	29·65	23·65
	9 ..	27·7	28·8	26·6	22 ..	21·7	26·2	23·2
		27·3	28·6	26·4		22·9	25·7	24·9
	11 ..	25·6	26·6	26·7	24 ..	24·4	27·25	24·85
		27·1	28·4	26·4		24·9	28·2	24·4
Plots not mulched.	2 ..	25·9	27·7	25·9	13 ..	24·3	28·4	23·6
	..	26·2	28·9	25·0		24·4	28·85	23·25
	4 ..	23·1	25·6	25·2	15 ..	25·2	28·8	24·1
		25·6	27·9	25·4		24·6	29·05	23·25
	5 ..	25·1	26·3	26·5	18 ..	21·0	25·2	23·5
		24·0	24·7	27·0		21·8	25·8	23·7
	7 ..	25·7	27·5	25·9	20 ..	25·2	30·1	22·8
		24·1	25·5	26·3		24·6	29·6	22·7
	10 ..	27·6	29·6	25·7	21 ..	24·6	29·1	23·2
		26·6	28·7	25·6		24·5	29·6	22·6
	12 ..	24·0	26·3	25·4	23 ..	24·3	26·6	25·4
		25·3	26·9	26·1		22·7	25·7	24·7

A perusal of the complete moisture data showed appreciable variations in the moisture contents of the clay band (23-43 cms.). Notwithstanding the apparent uniformity of the texture of this horizon, as judged by the eye, the apparent correlations between duplicate samples strongly suggested that the soil texture varied more than was suspected. For this reason, "sticky point" determinations (6) were made on the samples for this depth, and Table I. shows the summary of these determinations, together with the "moisture content" determinations,

The correlation coefficient between the moisture content and the "sticky point" for the 24 samples taken on the 19th December was + .860, and the regression of the "sticky point" on the "moisture content" was .813. The correlation coefficient for the second sampling, taken 1st May, 1929, for this depth was + .912, and the regression of the "sticky point" on the "moisture content" was .955.

Over this short range, the relationship between the "sticky points" and "moisture contents" at the time of sampling may be expressed approximately by the relationship "Sticky Point" = "Moisture Content" + K, where K is a constant for the particular treatment and sampling considered. The "moisture contents" corrected for texture on this basis are shown in columns 4 and 8 of Table I.

TABLE II.

Moisture Contents of Mulched and Non-Mulched Soils.

Depth (cms.).	Weight / Volume.	First Sampling, 19th December, 1928.			
		Moisture Content.		Water Conserved by Mulching.	P.
		Mulch.	No Mulch.		
		%	%	mms.	
0–10 ..	1·51	6·38	60·02	0·54	·5
10–23 ..	1·51	12·89	10·83	3·11	·01
23–43 ..	1·87	26·26	25·83	1·61	·05
43–63 ..	1·36	27·11	27·81	..	..
63–93 ..	1·49	25·03	25·56	..	..
93–133 ..	1·52	23·08	24·61	..	·05
133–173 ..	1·59	21·76	21·22	..	..
173–213 ..	1·50	21·11	21·47	..	..
Total ..	..	..	..	5·26	..

Depth (cms.).	Weight / Volume.	Second Sampling, 1st May, 1929.				Loss in Plots Not Mulched between 19.12.28 and 1.5.1929.	Remarks.
		Moisture Content.		Water Conserved by Mulching.	P.		
		Mulch.	No Mulch.				
		%	%	mms.		mms.	
0–10 ..	1·51	3·84	3·52	0·48	·01	3·8	Depth of mulch
10–23 ..	1·51	6·70	6·44	0·51	·7	8·6	Surface soil
23–43 ..	1·87	24·23	23·57	2·49	·05	8·5	Clay band
43–63 ..	1·36	25·75	25·64	·30	·8	5·9	Clay with limestone nodules
63–93 ..	1·49	23·34	23·90	..	..	7·4	
93–133 ..	1·52	22·61	22·98	..	..	9·9	
133–173 ..	1·59	20·83	20·30	..	..	5·9	
173–213 ..	1·50	21·68	20·41	..	..	6·4	
Total ..	..	..	..	3·78	..	56·4	

"Sticky point" determinations were also made on the 24 samples from the surface soil depth 10-23 cms. of the first sampling, but it was found that the samples agreed so closely that no correction was necessary for the variation in texture of this depth. The mean of these determinations was 14.33, and the standard deviation 0.73. The "sticky points" were therefore not determined for this depth in the second sampling, or for the depth 0-10 cms. in either sampling.

As it was apparent from the moisture determination results that no significant differences were present in samples below the depth of 43 cms., no "sticky point" determinations were made for this depth. In any case, the interpretation of the "sticky point" values would have been difficult, owing to the presence of limestone concretions in the samples.

In Table II. the results are summarized, showing the mean moisture content of each depth for the mulched and not-mulched plots at each sampling, together with the volume weight of the soil at each depth, and the excess of moisture found in the plots that were mulched over that found in the plots that were unmulched. This latter quantity represents the moisture that was "conserved" by the mulch, and is expressed in its equivalent depth of irrigation or precipitation.

In columns 6 and 10, the probability P that such a difference as is observed in the mean moisture contents for the various depths at each time of sampling could have occurred by chance is given.* Where P is .05 or less, the difference may be considered as significant.

The large sampling error noted in the surface 10 cms. at the time of the first sampling was due to the difficulty of sampling the loose mulch, and also to the large moisture gradient at this depth, which would cause appreciable differences in the moisture content of samples if the sampling were not strictly uniform, with regard to the amount of soil taken from the top to the bottom of the sample.†

At the time of the second sampling, the difference in the first 10 cms., amounting to 0.32 per cent. of water in favour of the mulched plots, is definitely significant. Although this is only a small amount of moisture, it is difficult to understand why the samples at this depth from the unmulched plots should be drier than those of the loose soil of the mulched plots. It is possible that the loose mulch absorbed more hygroscopic moisture during the autumn than the more compact surface soil of the unmulched plots, or posssibly the difference is due to a systematic sampling error, i.e., a possible tendency to take a greater proportion of soil near the bottom of the mulch when sampling than near the top, owing to the difficulty of sampling the loose mulch. In any case, the small difference observed at this depth, i.e., 0.48 mm., is of little practical importance. However, a significant difference in favour of the mulch plots occurs at the depth 23-43 cms.

A rather large sampling error was unavoidable below 43 cms., owing to the presence of limestone nodules, and the general heterogeneous nature of the soil. There was no reason to expect that the dispersion of moisture contents of the samples was different for different depths, and on this assumption, the standard deviation of the moisture content of the samples of these depths was estimated for each of the two samplings from the 120 samples of each sampling to be 1.427 for the first sampling and 1.308 for the second sampling, the standard errors of the difference of two means of samples of twelve would therefore be 0.58 and 0.53 respectively. It is seen that with the exception of the depths 93-133 of the first sampling and 173-213 of the second sampling, in no cases do the differences exceed twice these values.

* Determined by "students" method described by R. A. Fisher—"Statistical Methods for Research Workers," 1928, pp. 104-112. Oliver & Boyd.

† The moisture content of the mulch does not appear to be as important from practical considerations as that of the soil below.

It is difficult to account for these two exceptions, but the differences observed in these two cases could hardly in any way be explained by the different treatments to the surface.

One can safely conclude that no significant differences in moisture content due to the different treatments occur below the depth of 43 cms. The small excess of moisture found in the depth 43-63 cms. of the second sampling has been included in the total moisture conserved, as it is possible that it represents moisture conserved, but this small difference could easily be explained by chance variation.

It is seen, then, that after a period of 30 days, the moisture content of the mulched plots exceeded that of the plots not mulched by 5.26 mms. of water. Only a small part of this could be attributable to chance, and most of the excess water was found in the sandy loam surface soil immediately below the mulch.

During the nineteen weeks that elapsed between the first and second sampling, the surface soil dried out to an air dry condition, and the clay subsoil lost water more or less throughout, the amount lost decreasing from about 2.3 parts of moisture per cent. of dry soil nearer the surface to about 1 part per cent. at the lower depths sampled. This loss, of course, was probably partly due to slow downward movement and upward movement and evaporation from the surface.*

At the time of the second sampling, the mulch plots contained an equivalent of 3.39 mm. of water more than the unmulched plots. The greater part of this excess was found in the clay band (23-43 cms.); in fact, this was the only part of the soil in which significant differences could be definitely ascribed to the different treatments.

The different depths at which the greater part of the moisture conserved in the mulched plots over that in the unmulched plots at the times of the two samplings is to be noted.

It is interesting to note the small change in moisture content of the soil, even after a long period of hot dry weather, in the absence of plant growth.

It also appears that under the conditions of this experiment, and on this soil, the effect of a soil mulch on the moisture retained by the soil is very limited, and of no practical importance.

5. Temperature Data.

For the purposes of determining whether the soil temperatures in the experimental plots were similar or not to those that would occur in the open field, thermometers were placed at depths 15 and 30 cms. in two mulched and two unmulched plots, and for purposes of comparison in two positions of two "temperature check plots" each 24 feet by 12 feet laid out near the experiment, on one of which a soil mulch was dug after irrigation, while the other was left untouched except for the removal of weeds, in a manner similar to the experimental plots. The thermometers were placed at the 15 and 30 cms. depths as in the experimental plots, and also at 60 cms. deep. The bulbs of a Negretti and Zambra soil thermograph (with two bulbs) were placed in one of the positions of the mulched and not-mulched plots at 15 cms., in lieu of the thermometers at this depth and position.

* The movement might have occurred either in the liquid or vapor phase.

After the mulch was dug, the surface of the soil was in all cases about 2 cms. higher than before digging, but the depth of the thermometers was measured from the original surface level, so that the thermometers at 15 cms. depth on the mulched plots were 5 cms. below the "mulch."

As before mentioned, the experimental plots were sheltered from all rains; but the "temperature check plots" were necessarily exposed to the rain that fell.

At first, the temperatures were taken once daily at 9 a.m., but from 9th January, 1929, until the completion of the experiment, the temperatures of the 15 and 30 cms. depth were taken twice daily, at the times of the maximum and minimum temperatures, which were determined by taking periodically a complete series of readings every two hours for 36 hours, and plotting the results.

On the formation of the mulch, the mean temperatures on the unmulched plots began to rise higher than those on the mulched plots at all depths.

For the period 9th January to 22nd March,* the mean differences of the daily mean temperatures (mean of unmulched minus mean of mulched plots) were as follows:—

Depth.	*Experimental Plots.*	*Check Plots.*
15 cms.	0.37° C.	1.91° C.
30 cms.	0.07° C.	1.26° C.

It is apparent that, owing to the high conductivity of the iron partitions, the difference in the mean temperatures observed in the "temperature check plots," despite the precautions taken, has been largely eliminated in the experimental plots.

The period covered by these figures included the peak of the warming period, when differences were greatest. The cooling period could not be included owing to repeated rains. During this latter period the difference between the temperatures of the mulched and not-mulched plots becomes less and would finally be reversed, the mulch plots becoming warmer than the not-mulched plots. The actual discrepancies between the mean temperatures of the mulched and not-mulched plots were therefore not quite as great as the above figures indicate.

Taking into consideration the limited amount of moisture lost from the period between the first and second sampling, it is unlikely that the results would have been materially altered if the experimental plots had followed the temperature check plots more closely.

6. Summary.

An experiment was carried out on undisturbed field soil to determine the effect of a soil mulch obtained by digging the soil to a depth of 10 cms. on the amount of moisture remaining in the soil after a period of time.

Twelve inches of water was applied at the outset, an amount sufficient to wet the soil to a depth of at least 6 feet.

* Data after this date is hardly comparable, owing to several heavy falls of rain.

No water was applied, either as rain or otherwise, after the formation of the mulch, and no plant growth was permitted.

After a period of 30 days the mulched plots contained the equivalent of 5.26 mms. of water more than those not mulched.

After a period of 23 weeks the difference was equivalent to 3.39 mms. of water.

Owing to the conditions of the experiment, the differences in soil temperatures between the mulched and not-mulched plots were not as great as found in the field. This may have modified the results to some extent, but it is considered unlikely that the results would have been greatly different if the soil temperatures had followed those observed in the field more closely.

Acknowledgment.

It is desired to express appreciation to Professor J. A. Prescott, Chief of the Division of Soils Research of the Council for Scientific and Industrial Research, for his help in reading through the original text, and for his valuable comments and suggestions.

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The Control of Codlin Moth in Australia.

Notes on the Possible Utilization of Trichogramma (Hym., Chalcidoidea).*

By J. W. Evans,† B.A.

1. Introduction.

On account of the possibility of economically controlling codlin moth and other insect pests, by means of egg-parasites of the genus *Trichogramma,* an investigation into all the aspects of the problem was recently undertaken by the Division of Economic Entomology. Although no results have yet been obtained which can be considered of immediate practical interest to orchardists, it is felt that the publication of a preliminary report setting out briefly the present position of this investigation will be of interest to entomologists both in Australia and abroad.

2. Historical.

(*a*) *Early Records.*—In spite of the fact that it is only comparatively recently that these minute hymenopterous egg-parasites have become the subject of so much interest and speculation, yet they have been known to entomologists for over a century, since Webster—(1) considered that the parasite bred from the eggs of *Caliroa cerasi* by Peck in 1797, (2) and determined by Westwood as an Encyrtid, was in reality *Trichogramma* (*Pentarthron*) *minutum,* Riley.

Towards the end of last century, it was recorded by Riley (3) in the United States of America, but it was not until 1901 that it attracted the attention of entomologists and orchardists in Australia, when Mr. W. A. Boucher (4), a New Zealand Orchard Inspector, having remarked the inconsistency of the reports of the prevalence of codlin moth in the same districts decided to investigate the matter, and discovered the presence of a parasite in the eggs of the pest at Waikumete. The insects were forwarded by the New Zealand Department of Agriculture to Washington, and identified by Dr. L. O. Howard as *Trichogramma pretiosa,* Riley.

When during 1902, close watch was kept on the activities of the parasite, it was discovered that few individuals had survived the winter, and that, although they multiplied rapidly in the spring, they did not become numerous enough to destroy the eggs of the codlin moth sufficiently to reduce perceptibly the percentage of infested fruit until the season was well advanced.

(*b*) *Previous Investigations into the Economic Possibilities of Trichogramma.*—Throughout this century, numerous observations

* Manuscript submitted for publication, 30th November, 1929.

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have been recorded of the control of various lepidopterous pests by *Trichogramma,* and for a few years prior to the war many investigations were initiated, special interest being taken in the possibility of controlling codlin moth in Russia.

It is not intended to attempt here a summary of the voluminous literature that has accumulated on the subject of *Trichogramma,* but a few references to early work in connexion with it will not be out of place. Attention has already been drawn to the observations of Mr. Boucher in New Zealand to the effect that reports on the prevalence of codlin moth in a given district were not consistent, due to the presence of egg-parasites in some orchards and not in others. Similar discrepancies were noticed elsewhere, so that it was supposed that *Trichogramma* was scattered in its distribution, and in consequence it was sent from heavily infested localities to other areas in which it was not considered to be present. Importations were even made into certain countries, one of the earliest being a consignment of *Trichogramma* sent to Sumatra from the United States for use against *Heliothis obsoleta* F. on tobacco. (5).

Needless to say, no permanent results were obtained as a result of these liberations, since it was not then generally realized that in all probability representatives of the genus are universally distributed, and that the frequent occasions on which pests have been controlled by these insects have probably been due to a certain interaction of factors, both biological and climatic, operating in a restricted area.

The idea of multiplying *Trichogramma* in the laboratory also occurred to many of the earlier workers with this parasite, and among the hosts utilized were *Agrotis* (*Euxoa*) *segetum,* Schiff, in Russia (6), and *Mocis undata* F., in Java (7). It was also suggested in Barbados in 1915 (8), that for the control of the cane-borer, *Diatraea saccharalis* F., *T. minutum* should be bred in captivity and liberated at intervals. However, it was not until 1926 that a really satisfactory method of breeding it in large numbers was devised, when Flanders (9) by using *Sitotroga cerealella* Ol. as a host, succeeded in producing 200,000 *Trichogramma* a day. More recently he has published a short paper (10), outlining the equipment necessary for producing a million parasites a day, and giving in a concise form directions for using the apparatus described. His technique has been copied and modified by several entomologists in various parts of the world, and the author, though basing his method of rearing *Sitotroga* and *Trichogramma* on that used by Mr. Flanders, has also received assistance from Mr. A. B. Baird of the Entomological Laboratory, Chatham, Ontario, and from a report furnished by Dr. Tillyard on the technique of Mr. D. W. Jones of the Corn Borer Laboratory, Arlington, Mass., Dr. Tillyard having visited this laboratory during 1928.

3. Presentation of Problem.

All the numerous records of a pest having been controlled or partly checked, due to the activities of *Trichogramma,* have referred to infestations in the autumn or late summer, and it has been suggested that the reason for the scarcity of the parasite in the spring has been mainly owing to the shortage of the hibernating eggs available during the previous autumn. This is no doubt, in part, correct, but it is most probable that only a few of the parasites in hibernating eggs manage

to survive the rigours of winter; that those few which do emerge are very feeble, and that of them only a very small proportion have the strength to oviposit.

This supposition is borne out by experimental evidence, since eggs of *Ephestia kuehniella* Zell., parasitised in the laboratory by *Trichogramma*, although they gave rise to healthy parasites after three months in a refrigerator set at 2° C., failed to do so when the temperature was not kept constant. In the latter instance, when the temperature fluctuated between 1° and 10° C., only a small percentage of the eggs that had been parasitised gave rise to adult Chalcids; the majority of these emerged in a very poor condition, seldom fully developing their wings, and generally dying within an hour of emergence; while those insects that did succeed in ovipositing laid very few eggs and soon also succumbed. It is therefore reasonable to suppose that larvae and pupae exposed in the open in hibernating eggs would be similarly affected.

It has been mentioned above that *Trichogramma* is probably universally distributed, and it is probable that the genus in addition to containing certain species differentiated from each other by morphological characters has also numerous physiological strains or races that inhabit different environments, and possibly in some cases are confined to a single host or group of hosts. Therefore the problem does not merely consist of the introduction of a foreign strain, though this may be of value in special cases, but of the liberation at the right time of quantities of insects. These, in the author's opinion, should actually have been bred from a strain of the parasite obtained in the field, found already infesting the eggs of the pest which it is proposed to control. Although three introduced strains of *Trichogramma* will be tested in the field for use against codlin moth in Australia, these being *T. evanescens* Westwood (two strains), and *T. minutum*, Riley, yet it is eventually proposed to obtain parasites (*T. australicum*, Gir.), which are already established here, and are, in fact, probably indigenous. The last-named are known to effect a partial check on the codlin moth in late summer (11), and it is proposed to breed them up under artificial conditions, so as to have large numbers ready, not only to attack the eggs of the first brood, laid in the spring, but also the eggs of subsequent broods.

4. Experiments with various Hosts.

(*a*) *Tribolium castaneum* Hbst.—Although *Sitotroga* can be bred quickly and easily under artificial conditions, yet entomologists in America have experienced considerable difficulty in maintaining a constant stock of this insect on account of the ravages of the predaceous mite, *Pediculoides ventricosus*, Newp. Therefore, Dr. Tillyard decided that a search should be made for a more suitable host, and suggested that first of all flour beetles of the genus *Tribolium* should be tested, Professor R. Chapman of the University of Minnesota having demonstrated the simple manner in which these insects can be bred and their eggs isolated. Accordingly, early in August, 1928, investigations were commenced in England at the Parasite Laboratory (Farnham Royal) of the Imperial Bureau of Entomology. A supply of *Tribolium castaneum* was obtained and kept in flour contained in jars, in an incubator registering 27° C. At this temperature, the beetles oviposited readily, and in order to obtain eggs, the flour, having

first been sifted through 40-mesh bolting silk, which removed the beetles and larvae, was then passed through a sieve having a 76-mesh. This retained the eggs, which were stuck on to cards with gum tragacanth.

The parasites displayed little interest in these host eggs, and in most cases having surveyed them, by running round and over them, tapping them with their antennae, moved off. Although oviposition was never observed, it did take place, and in three out of eight experiments parasitised eggs were obtained. These hatched after periods ranging from three to six weeks, at a temperature between 20 and 22° C., but in all cases the parasites emerged in a very enfeebled condition, dying within an hour and never ovipositing.

In one experiment, eggs of *Tribolium* were mixed with some laid by the Mediterranean flour moth, *Ephestia kuehniella;* all the latter were parasitised and gave rise to adult Chalcids, but only eight of the 28 *Tribolium* eggs presented turned black (a sign that parasitism has been effected), and out of these, only one emerged.

It was considered possible that the slightly floury surface of the beetle eggs deterred the Chalcids from ovipositing in them, but this was subsequently disproved, as when the eggs of the Angoumois grain moth, *Sitotroga cerealella,* were presented to them, although they were parasitised successfully, greater attention was paid to the small lumps of cornflour retained by the sieve with the eggs. While it was discovered that oviposition never actually took place in these lumps, on several occasions they were observed to be covered with parasites, although the nearby eggs were entirely deserted. It is probable that the attraction exercised by the grains was due to their retaining more of the odour of the moths than did the eggs, since it is by means of certain sense-organs situated in their antennae that the parasites find their hosts, and it is certain that they do not recognize eggs as such. Attempted egg-laying has also been observed in waxy lumps, present on the cards bearing the eggs of *Ephestia,* these lumps being possibly the excreta of the moth.

So it is apparent that lepidopterous eggs have a greater attraction for such races of *Trichogramma* as have been tested, than have those laid by beetles, although it is known that in the field they do not confine their attention to the eggs of the first-named order.

(*b*) *Ephestia kuehniella* Zell.—After it had been demonstrated that the eggs of *Tribolium* were useless for the purpose, and that the eggs of another flour beetle, *Rhizopertha pusilla* F., also gave negative results, none of the latter even being parasitised, the eggs of *Ephestia kuehniella* were utilized. This moth was bred on "Quaker" oats, though it will also feed on flour, wheat, meat, and other substances. The insects can be reared at room-temperature; the period taken for development under these conditions is not known, but at a temperature between 24 and 27° C. with a relative humidity of 80 per cent. they complete their life-cycle in six weeks.

If the moths are bred on a relatively small scale a simple way of handling them is to place rolls of corrugated cardboard in the jars containing the oats; the larvae when full-fed will pupate in these, and the pupae can thus be used as required, being either placed in cold storage or in an incubator, according as to whether it is desired to retard or accelerate their development. The moths are collected by means of

the electric sucking machine, described later in this paper, and transferred to oviposition tins. These consist of metal cylinders with removable tops and bottoms, the latter being made of 20-mesh wire gauze, and the tops having apertures equal to or slightly greater than that of the nozzle of the sucker.

The tins stand in petri-dishes, and contain flour to the depth of a quarter of an inch. After the moths have been emptied into the receptacles corks are placed in the apertures, and every day the flour is shaken out, without the tins being opened, and it is sifted through a 78-mesh bolting silk. The residue, which consists of eggs, legs, &c., being then sieved through a 50-mesh silk, which retains the debris while giving passage to the eggs. These are readily parasitised by *Trichogramma,* but their disadvantage lies in the fact that if, of a batch of eggs, some escape being parasitised, as almost invariably happens, the emerging larvae eat the surrounding eggs, in addition to webbing together those that escape being thus destroyed.

(*c*) *Ephestia elutella* Hb. and *Endrosis lactella* Schiff.—Other hosts tested were *Ephestia elutella* Hb., a pest of stored cacao beans, and *Endrosis lactella* Schiff., which was bred on horse-beans (*Vicia faber,* var. *equina*), and feeds on a variety of other substances, being principally recorded as a rubbish feeder.

Although *Trichogramma* was induced to oviposit in the eggs of both the above-mentioned moths, only the latter held out any promise of being suitable for breeding in the laboratory in large numbers, and further investigations will be made with this insect. A list of other possible hosts has been compiled, which will be tested as opportunities occur, and providing that the insects are already in Australia.

(*d*) *Sitotroga cerealella,* Ol.—Eventually, it was decided to procure a stock of *Sitotroga,* and since difficulty was experienced in locating an infestation of this moth in England, eggs were obtained, together with a consignment of *T. minutum* from Mr. Baird in Canada.

This insect, which is a widely distributed pest of corn and wheat, attacking it, not only when stored, but also in the field, breeds only under warm, moist conditions. At a temperature of 27° C., with a relative humidity of 80 per cent., its life-cycle is completed in four weeks. At Farnham House, the moths were reared in a cage in the cellar, where a temperature between 24 and 27° C., was maintained, the relative humidity being 80 per cent. Flanders (10), states that a relative humidity of 60 per cent. is sufficient with a temperature of 24° C.

Although no trouble was experienced with *Pediculoides,* another mite, of the genus *Tyroglyphus,* occasioned considerable annoyance, when the moths were bred in small receptacles, in a hot, moist incubator. These mites are mainly feeders on mouldy wheat and frass, though they were proved on more than one occasion to be killing live dipterous pupae kept in the same incubator. However, the irritation due to them, both mental and physical, was of more consequence than the slight mortality they may have brought about among the larvae and pupae of *Sitotroga.* When it was realized that *Sitotroga* was more satisfactory than any of the other hosts experimented with, and it had been decided to breed it on a comparatively large scale, experiments were made in sterilizing the wheat, and while fumigation with

carbon bisulphide was proved to be useless, a dry heat of 52° C. applied over a period of eight hours was found to kill not only the mites themselves, but also the highly resistant eggs.

5. Systematics and Bionomics.

(*a*) *Synonymy.*—The question of the synonymy of the species included in the genus is somewhat involved, and although a number have been described, yet it is probable that all the European ones at least are synonymous with *Trichogramma evanescens,* Westwood. But Ferriere and Faure (12), who have studied this group and are of this opinion, consider that possibly the American form, *T. minutum,* Riley, may be distinct.

To the working biologist, however, the question of nomenclature as decided by morphologists is of not such great import as is the differentiation of the various physiological or biological races. The author has studied, in the laboratory, two forms from widely separated localities; specimens of both were examined by Dr. J. Waterston of the British Museum, who considered them to belong to the same species. One of these races consists solely of parthenogenctic females, and was discovered in the eggs of the Pine Tortrix, *Rhyaciona buoliana* S.V., in England, while the other was obtained from Professor A. Hase, who has published an exhaustive paper on the biology of this insect (13). This strain is bisexual, though unfertilized females give rise only to male progeny. This particular strain of *Trichogramma* was found originally in the eggs of *Pieris brassicae* L., *P. napi* L., and *P. rapae* L., and, although morphologically identical with the first mentioned one, yet displays marked colour differences, in addition to others of a physiological nature. For instance, the length of the life-cycles of the two races differ, and it is also noticeable that, while the former race oviposit most efficiently in the shade, the latter are more active in a bright light. In Germany (14), during 1925, a 78-100 per cent. parasitism of the eggs of *Mamestra brassicae* L., *Pieris napi,* and *P. brassicae* was recorded on cabbages growing in the sun, while a much lower percentage of the eggs were parasitised on plants growing in the shade of trees.

(*b*) *Bionomics of Different Races—Author's Experiments.*—A series of experiments were carried out at Farnham House to determine the following points in connexion with the biology of *Trichogramma:*—

(i) The maximum number of eggs one *Trichogramma* is capable of parasitising.

(ii) Whether a parasite will search for scattered eggs, or, having found a batch, remain in the one place, ovipositing in the same ones over and over again.

(iii) The average length of the life of an adult individual.

(iv) At what period after emergence are most eggs laid.

(v) The length of the interval between generations.

The tests made were duplicated under identical conditions for the two European races of *Trichogramma.* The temperature was maintained at 25° C., the relative humidity was unknown, and a dim artificial light was kept on all the time. In the case of the experiments to determine the length of the life-cycles, *T. minutum* was also utilized, and with these tests the temperature was kept at 27° C., the

relative humidity at 60 per cent., and a bright artificial light was maintained. In view of the fact that this is only a preliminary report, tabular details are omitted, since they might only tend to confuse the issue.

It was found that one *Trichogramma*, of the obligatorily parthenogenetic strain, can parasitise 73 eggs of *Ephestia kuehniella*, but on an average only parasitises 41. The insect is most efficient during the first five days of its life, and at a temperature of 25° C. will live as long as 13 days, ovipositing even on the 12th day. Twenty eggs scattered over an area of 11 square inches were all parasitised within 36 hours by one *Trichogramma*, as were all the eggs of a batch of 20 deposited in a mass.

A fertilized female of the facultatively parthenogenetic strain can parasitise 99 eggs of *E. kuehniella*, but on an average only parasitises 62. The insect is most efficient early in its life, although in one experiment 19 out of 20 eggs were parasitised on the sixth day, six days being the average duration of the life of an adult at 25° C. Eggs laid by unfertilized females give rise only to male progeny, and fertilized females, while laying batches of eggs, giving rise to more females than males in the earlier part of their lives, yet sometimes if not re-fertilized later, lay only eggs that produce males.

While the duration of the life-cycle of the first-mentioned race is ten days at a temperature of 27° C., that of both the facultatively parthenogenetic races is nine days. The shortest period recorded for the development of the latter races to take place in was seven days; unfortunately, the temperature was not recorded in this instance, though known to have been in the neighbourhood of 30° C.

(*c*) *Comparison with the Greenhouse Whitefly.*—To the author's knowledge, no genetical research has been done with this genus, but the greenhouse whitefly, *Trialeurodes vaporarium* Westwood, which presents a similar case, has been studied by Thomsen (15), and Schrader (16). This insect has two strains, known respectively as the English and American forms. The former race consists solely of females, termed by Thomsen "obligatorily parthenogenetic thelytokous females," while the latter consists of "facultatively partenogenetic arrhenotokous females," with a diploid number of chromosomes; the latter if unfertilized, give rise only to haploid males. Marchal (17), considers that if observations were made on *Trichogramma* from various hosts and localities, a number of strains would be found having the status of races or elementary species, the formation of which has been helped by thelytokous parthenogenesis.

6. Technique of Trichogramma Production.

(*a*) *The Rearing of Sitotroga cerealla.*—An underground chamber in the laboratory, of which the width is approximately 6 feet, and the length 16 feet, is being fitted up as a breeding chamber. At one end is a cage, 4 feet long, 2 feet deep, and 2 feet high. The framework is of wood, and the sides, top, and bottom of 60-mesh phosphor-bronze gauze. There are two communicating compartments; the left-hand one is closed by double doors, under which is a tray that can be removed when the doors are shut. The right-hand division carries twelve trays. The top and bottom ones have gauze bottoms, and all four sides are 2 inches high. The intervening ten have perforated zinc

bottoms; and while the front, back, and right-hand sides are 2 inches high, the left-hand sides are $1\frac{1}{2}$ inches. Each tray has a strip of felt nailed along the front edge, which overlaps the top of the tray below. The compartment is closed by means of a panel, which fits into a groove at the base, and is held by hooks on top. The cage stands on a bench, in which an opening has been cut, of which the area is slightly less than that of the cage.

Every tray, excepting the top and bottom ones, is filled with wheat to within half an inch of the top, the grain having previously been sterilized by dry heat (52° C.). Newly hatched larvae are added with a fine camel-hair brush, and the temperature is maintained in the neighbourhood of 24° C., with a relative humidity of 65 per cent. The majority of the moths on emergence enter the left-hand compartment, through the $\frac{1}{2}$-inch space between the trays. No grain is placed in the trays with gauze bottoms; they merely serve to prevent the moths congregating anywhere in the right-hand cage, other than in the breeding-trays.

The moths are collected by means of a small electric-sucking apparatus specially constructed for the purpose. It has a switch on the handle, and the strength of the inward draught of air can be regulated. The moths are collected in a detachable cylinder, which, when filled, is placed over the funnel of an oviposition tin as described in connexion with the breeding of *Ephestia.* The moths are emptied into this and fall on to a thin layer of cornflour at the bottom, in which they oviposit. Eggs are obtained in the manner described for *Ephestia.* Every day, fresh moths are added to each tin, and the flour removed, sifted of eggs, and replaced, and every third or fourth day the tins are cleaned.

The moths which are removed, both those dead and alive, will be found to have eggs adhering to them; these can be removed by washing the insects in a strong stream of water, the eggs sinking to the bottom and the moths floating. Those moths that die in the breeding cage can be removed by emptying the tray in the left-hand compartment. The apparatus described above is only intended for the production of sufficient eggs for field experiments, since it is not proposed to establish a large "plant" at Canberra for distributing purposes.

(*b*) *The Breeding of Trichogramma.*—(i) *Rearing Technique.*—Shellac is thinly brushed on a round card on to which eggs are poured. After the card has been emptied of unstuck eggs, it is placed in the lid of a shallow petri-dish, which it fits exactly. One-sixth of a card of parasitised eggs is then placed face downwards in the dish, the bottom is put on, and held by a rubber band, and the dish placed upside down on a frosted-glass bench. This is contained in the same room as the *Sitotroga* breeding-cage. The room is divided into two by a fly-gauze screen, in which is a door, also of wire gauze. The bench is lit from below, the light being constantly on.

The card of parasitised eggs added to the fresh eggs must already have given rise to a few insects, or be due to hatch within twelve hours. Wishart (18) found that if parasitised eggs are kept in the dark, very few parasites have emerged at the end of the period required for total emergence, and that if they are then placed in a strong light, emergence is rapid and complete, and pairing takes place immediately. By this means, the ratio of reproduction can be considerably increased.

Another method is to place the egg-cards in earthenware jars, using the make that are of the same diameter from top to bottom. The jars are covered with petri-dishes, and placed inverted on the bench. The cards can be placed in cardboard postal boxes for mailing or storage. It is best not to rear the parasites in cardboard containers, since the edges of these are seldom even, and a number of insects will escape through the gaps where the cardboard does not quite meet the lid. Parasitised eggs can be kept for long periods in cold storage, provided that the temperature is kept constant. The temperature in the breeding-chamber (24° C.), is maintained by means of a combination electric radiator and fan, controlled by a thermostat, and the atmosphere is kept moist by means of a pan of water placed in front of the fan.

(ii) *Liberation in the Field.*—As yet the author has himself conducted no field investigations, so that for the method of liberating the parasites, reference must once more be made to Flanders' paper (10) :—

> "The egg-cards are placed in the field just as emergence begins. The cards are cut into sections of 10,000 eggs, and a fine wire several inches in length is attached to each section. Each section is suspended from the lower portion of the food plant of the host. An egg-card suspended by fine wire is protected to a greater degree from attack by predators than when in contact with the plant.
>
> Under normal conditions, emergence is completed in from three to six days. The parasites remaining on the card at the end of the time are usually males. Since the males tend to emerge prior to the females, mating is ensured. It is estimated that a section of 10,000 parasitised eggs is sufficient to cover at least 100 square yards of leaf surface to be protected."

The same author considers that the labour of one man for two or three hours a day is sufficient to maintain a production of 1,000,000 eggs a day.

It has frequently been noticed that those *Trichogramma* that have been fed on honey or other sugary substances, live longer and lay more eggs than those not so treated, and so it is suggested, that if a small raisin is stuck on each card of eggs exposed in the field, the parasites that feed might become more vigorous, and hence more efficient, than they would have been had they commenced their activities without a meal.

7. General Review of the Problem.

The efficiency of a parasite depends on many factors, two of the most important being its power of searching out its host and its egg-laying capacity. *Trichogramma* would appear to be haphazard in its method of looking for eggs in which to oviposit. Since, at any rate in a confined space, it will oviposit many times in one egg, nine punctures having been observed in a single *Ephestia* egg among a batch placed with a single parasite, the loss of potential parasites must be very great. Added to this, oviposition has frequently been observed in foreign bodies. Such activities cause a dissipation of vital energy and time, even if an actual loss of eggs does not take place.

It has already been pointed out that the actual egg-laying capacity of the two strains is very similar, although the period over which

oviposition is spread differs; so that there does not seem much to choose between an insect that lays 80 eggs over a period of twelve days, each egg giving rise to another female and potential parasite, and one which deposits a similar number of eggs over a period of six days, when only half of the eggs laid can be assumed to be going to produce females. The greater female-production powers of the first strain are balanced against the longer period over which eggs are deposited, since it is most probable that under natural conditions such small and delicate organisms seldom live more than a few days.

Other important factors to be taken into consideration are the polyphagous nature of *Trichogramma,* and its means of dispersal. It has frequently been suggested that its polyphagous nature is a factor which militates against its successful use in biological control work. Providing, however, that material is bred and liberated at the right time and place, and in sufficient quantities, such a habit would appear to be of direct advantage, since it would enable the parasite to live through the periods intervening between the appearance of the different broods of the pest, against which the attack is directed.

The means of dispersal are uncertain. It has been shown by Hase (13), that *Trichogramma* will travel one metre unassisted, and it may be assumed that the insects are carried great distances by the wind. Flanders (10) considers, "that the rate of dispersion from point of liberation varies directly with the temperature and light intensity, and inversely with excessive air-movement and surface-moisture."

8. Possible Extension for the Control of Other Pests.

Although the possibility of controlling codlin moth by means of *Trichogramma* has received a great deal of attention, yet this is not the only pest present in Australia that holds out a possibility of being controlled in this manner. Others are the pear slug, *Eriocampoides limacina* Retz; the Oriental peach moth, *Laspeyrisia molesta* Busck; and the tomato worm, *Heliothis obsoleta* F. Even these do not exhaust the list.

9. Conclusions.

This report is of a preliminary nature. The results attained so far, though promising, are naturally inconclusive. At an early date, field experiments will be initiated, which should supply more definite information as to the economic possibilities involved.

Should eventually it be considered that an economic and effective control of codlin moth can be attained by this method, recommendations will be made to the organizations concerned as to the best means of breeding and liberating the parasites in the various fruit-growing localities of Australia.

10. Acknowledgments.

Acknowledgment has already been made in the text of the paper to certain entomologists, to whom the author is indebted for ideas of which he has taken advantage. Special thanks are also due to Dr. W. R. Thompson, Superintendent of the Farnham House Laboratory of the Imperial Bureau of Entomology, for many suggestions and

frequent advice; to Professor A. Hase, for a supply of the race of *Trichogramma,* with which he has worked, and for the courteous reception and valuable advice given to the author on his visit to Berlin; and to Dr. Paul Marchal and Dr. J. Waterston. For assistance in the preparation of the paper, the author's thanks are due to Dr. R. J. Tillyard, Chief of the Division of Economic Entomology, at whose suggestion the paper was written; and also to Mr. A. L. Tonnoir, Senior Ecologist of the Division.

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Black Disease (Infectious Necrotic Hepatitis) of Sheep in Australia.

By A. W. Turner, M.V.Sc.

The following is a brief account of the Council's recent successful work on black disease of sheep. The investigations have been under the charge of Mr. A. W. Turner, M.V.Sc., assisted by Mr. D. Murnane, B.V.Sc., who has carried out the major part of the field work, as distinct from that of the laboratory. A progress report of the investigation was given in a previous issue (Vol. 2, No. 4 (1928), p. 205), but since that time further important results have been obtained, and it has been thought that some brief notes on the present position of the work and of the practical conclusions to be drawn from it would be of interest. The investigations will shortly form the subject of a more comprehensive bulletin.—Ed.

This disease, which received scientific attention for the first time some twenty years ago from the present Chief of the Division of Animal Health, Dr. J. A. Gilruth, has been the subject of a large amount of research by the Council during the last two years. Since Dr. Gilruth's early investigations, a great deal of valuable work had been carried out by various workers, particularly by the late Dr. Dodd, in New South Wales; but much work, especially regarding the prevention of the disease and the proof of its association with liver fluke, remained to be done.

Black disease is an acute infectious disease of sheep (and in rare cases of bovines) which is typically at its worst in late summer and early autumn, and affects both sexes alike. Its characteristics include a predilection for the best-conditioned animals, a high mortality with few or no premonitory symptoms, rapid decomposition of the carcasses, and a set of typical *post-mortem* appearances, the most constant features of which are the presence of yellowish to greyish irregular patches on the liver, and a marked accumulation of fluid, sometimes clotted into a jelly-like material, in the sac surrounding the heart. It is present in New South Wales, Victoria, Tasmania, and New Zealand, being known in the last two places as "braxy-like disease,"* and affects some of the finest sheep country in the Commonwealth. The records of its existence go back in New South Wales for about 60 years, and in Victoria about 55 years.

It occurs in well-watered country, supplied either by springs or rivers, or artificially by irrigation, indeed, in just that type of country that is conducive to the propagation and spread of the liver fluke; yet black disease by no means occurs wherever the liver fluke is found; for this to occur its combination with another factor, the causal organism, is necessary.

The mortality varies greatly in different seasons and different districts. It may range from less than 1 per cent. to as high as 70 per cent., while 10 per cent. to 25 per cent. is not uncommon.

As is inevitable when any idea of the losses caused by such a disease can be gained only through voluntary statements of breeders, it is difficult accurately to estimate the economic importance of black disease. However, in New South Wales, it was estimated by Cleland, in 1913, to cost that State £100,000 annually. Dodd, in 1918, increased this sum to £500,000; while last year, Edgar and Rose, taking into account its undoubted spread, considered that £1,000,000 yearly would not be an

* This disease is not to be confused with the "braxy-like disease" (Beverley disease) of Western Australia, which is caused by a distinct bacillus.

excessive estimate. When it is considered that the losses in Victoria and Tasmania are not included in that figure, it seems that the annual loss to Australia due directly and indirectly to this disease may be well over £1,000,000.

The chief results of the Council's investigations, and the practical conclusions to be drawn from them, are discussed in the paragraphs that follow.

Firstly, the disease in Victoria (in which for convenience most of the work was carried out) has been found to be much more prevalent than had been previously recognized; in fact, many farmers in the northern irrigation districts of Victoria have voluntarily reduced the carrying capacity of their properties through fear of heavy losses, and not a few have been forced to abandon sheep rearing altogether.

The causal organism of the disease has been identified as a race of the *Bacillus oedematiens,* which first came into prominence as one of the principal germs associated with the dreadful wound complication, gas gangrene, in troops during the Great War.

The association of the disease with liver fluke, first insisted upon by Dodd, has been amply confirmed.

Definite information that it is insidiously spreading has been accumulated, and it has been shown to be spread by the movements of flocks from affected to "clean" farms.

By subjecting experimental animals to the action both of flukes and of spores of the causal organism, it has been found possible to infect them artificially with black disease, so that the evidence of the role of the liver fluke in the disease is now well established. A finding of some importance has been that it is possible to produce an essentially similar disease in experimental animals (rabbits) by combining the action of spores of the causal bacillus with that of a totally different liver parasite (an hydatid), or even with that of chemical liver-irritants, so that the theoretical possibility of the disease's occasional occurrence in the absence of liver fluke, as reported by one worker in Victoria, must now be admitted.

A large number of experiments have been concerned with the question of the existence of spores of the causal organism in apparently healthy sheep in a state of latency, or one might say, suspended animation. It has been shown that the swallowing of spores, or the injection of them artificially, leads to their being transported to the internal organs, particularly to the bone marrow, the spleen, and (what is of importance from the point of view of the evolution of the disease) the liver. In the body the spores persist in their resting stage for unexpectedly long periods, for at least nine months, being potentially dangerous, but harmless, unless the liver is injured in some way. Since in sheep the commonest way in which the liver is injured is by the burrowing through it of the young immature flukes, it happens that liver fluke is to all intents the essential secondary factor that precipitates the disease.

A very important phase of the investigation has been that dealing with the prophylactic vaccination against the disease. A perfectly safe vaccine has been developed, one that contains no living germs, and which, therefore, cannot possibly give rise to bad results on injection. It has been shown experimentally to produce a good degree of immunity against the actual injection into the one sheep of sufficient living bacilli to

kill 20 unvaccinated sheep. In the field it has been tested in controlled experiments, in which only 50 per cent. of the flocks have been inoculated. As a result, it was found that the two injections recommended (at an interval of one month) reduced the mortality by 75 per cent.; while a third inoculation, such as is practicable on the small closer settlement holdings in the irrigation districts, caused a total cessation of deaths.

Since then, through the valued co-operation of the Victorian Department of Agriculture, the vaccine has been applied extensively in the field in Victoria, about 28,000 sheep having been inoculated with absolutely no bad results attributable to the treatment, and 12,000 doses have been forwarded to Tasmania. The general opinion of the breeders concerned is distinctly favorable to the treatment. In addition, a limited experiment has been carried out on the use of an anti-toxin in checking the disease, in which favorable results were obtained. Of course, the latter treatment is expensive, and, therefore, only suitable for stud stock, but it has the effect of immediately being effective, instead of requiring some weeks for the development of the immunity.

The practical applications of the above results are many. Firstly, the fact that we now definitely know what the causal organism is has allowed us to avail ourselves of the wealth of research carried out on the *B. oedematiens* from the human point of view during the war.

The proof of the interdependence of the bacillus and the liver fluke in the causation of the disease has strengthened our methods of combating it by providing two points of attack; for it is obvious that the disease may be prevented either (*a*) by making the animal immune against the bacillus, or (*b*) by preventing flukes from entering its liver, or (*c*) better still, by combining the two methods, so as "to make assurance doubly sure."

The control of liver fluke has already been fully investigated by the Council's Veterinary Parasitologist, Dr. I. Clunies Ross,* and by others, and their recommendations have been adopted. They consist of—(*a*) the treatment of the edges of watercourses, springs, marshes, &c., with powdered copper sulphate (bluestone), so as to destroy the freshwater snails that carry the fluke; and (*b*) the drenching of sheep with the new drug, carbon tetrachloride. Unfortunately, carbon tetrachloride is really efficient only against the adult flukes that have reached the bile ducts of the liver, and has little action on the young wandering flukes that bring about the infection with the bacillus; hence treatment with this drug is more of indirect benefit, since it kills off the adult flukes, and thereby prevents the contamination of pastures with fluke eggs: so far as black disease is concerned the benefits from its action would be more apparent in the season following its administration. The same disadvantage is attached to use of copper sulphate, since it has no action on the cercariae (encysted young flukes) already on the pasture, but removes the intermediate host, thus preventing fresh contamination.

It thus appears that vaccination should be of more direct benefit. It should, however, be carried out a few months before the black disease season, in order to have the animals immune before mortalities are expected to commence. For this purpose the first inoculation should be performed about October, the second in November.

* See "Liver Fluke Disease in Australia: its Treatment and Prevention," by I. Clunies Ross; Council for Scientific and Industrial Research, Pamphlet 5 (1928).

Another necessary control measure, first stressed by Dr. Gilruth, is the disposal of all carcasses. This should be done preferably by burning, but where it is impracticable, carcasses should be brought together and buried in an unused paddock.

This precaution is the more important owing to the existence of carriers of latent spores. From the research work outlined above it is conceivable that the disease could be introduced to a " clean " property through apparently healthy sheep from infected districts; the death of such " carriers, " up to at least nine months after their introduction, from any cause whatever, if the carcasses were allowed to rot might heavily contaminate pastures with the causal organism. This is a serious problem, as yet unsolved, for apparently the state of latency is not affected by vaccination.

In conclusion, it is felt that the Council's investigations, coupled with the research work performed by officers of the States concerned, have at least opened the path to the goal of the complete elimination of this serious disease, and that, as a result, a source of some of the wastage in the wool industry will have been removed, with a consequent proportionate lowering in the cost of production.

Trypanosomes in the Blood of Victorian Animals.

*By A. W. Turner, M.V.Sc., and D. Murnane, B.V.Sc.**

PAPER 1.

A Preliminary Note on the Occurrence of *Trypanosoma theileri* in the Blood of Cattle.

The blood parasite that is now known as *Trypanosoma theileri* was discovered in 1903 in the blood of cattle in South Africa by Sir Arnold Theiler, who at first regarded it as the cause of East Coast fever. At the present time, however, it is generally considered to be non-pathogenic; at any rate, there is no evidence that it is harmful.

Under various names, of which only *T. theileri* is now accepted, it has been recorded in many parts of the world, including Somaliland, Tunis, Algiers, England, France, Denmark, Sweden, Germany, Russia, Greece, India, Singapore, Annam, Japan, the Philippines, United States of America, Canada, Panama and Uruguay; but apparently it has hitherto escaped detection in Australia.

It is generally described as being about 60 to 70 μ† long by 4 to 5 μ wide, though smaller, presumably immature forms 25 to 30 μ long have been reported in some countries.

Under ordinary circumstances, it is present only in very small numbers in the blood of infected animals, in which case special methods

* Messrs. Turner and Murnane are veterinary research officers of the Council and by kind permission of the authorities concerned are stationed at the Veterinary Research Institute, University of Melbourne.

† The sign " μ " represents one-thousandth of a millimetre, or approximately one-twenty-five thousandth of an inch.

have to be employed to reveal its presence. Exceptionally, however, as when the resistance of the host is lowered by intercurrent infections such as East Coast fever, piroplasmosis (tick fever) rinderpest, surra or foot and mouth disease, it may become sufficiently numerous to be seen readily in ordinary blood smears. In such cases, one is at least justified in questioning whether the trypanosome is really quite harmless; it is possible that it helps to exaggerate the condition, or initiates a vicious cycle.

Theiler claimed that it is carried by the horse-fly *Hippobosca*, but there appears to be some doubt about this. Nöller has recently shown, in Germany, that it can be carried by the biting fly *Haematopola pluvialis,* in the gut of which it exists in an immature (crithidial) form, and that similar immature forms may be found in the March-fly *Tabanus glaucopis*. It is highly probable that March-flies of various species are the main carriers.

The purpose of this note is to record the presence of an apparently non-pathogenic large trypanosome, morphologically similar to *T. theileri,* in the blood of a cow.

Having shown the existence of the sheep trypanosome, *T. melophagium,* in Australia, we considered it worth while to search for the cattle trypanosome, particularly as we had been urged to do so by Sir Arnold Theiler during his recent visit to Australia at the invitation of the Council. For the purpose of a preliminary examination, defibrinated ox blood collected at the Melbourne city abattoirs was laked with an equal volume of fresh distilled water and centrifuged well for 20 to 30 minutes, after which the supernatant fluid was decanted and the deposit, consisting mostly of leucocytes and red cell debris, was examined between slide and cover slip under the microscope.

In one case out of twelve bloods examined, a few large trypanosomes not so active as the sheep species were seen. Two specimens were obtained in smeared-out deposit, one of which is shown in the appended illustration. They measured respectively 52.5 μ by 3.75 μ and 66 μ by 4 μ.*

We have not attempted to discover the intermediate host, or carrier, in Australia; but probably it will be eventually shown to be a March-fly.

It may be expected that a careful search for this trypanosome in smears of cattle blood will reveal its presence in a certain percentage of cases, particularly in the more tropical parts of Australia, where piroplasmosis occurs.

PAPER 2.

On the Presence of *Trypanosoma melophagium* in the Blood of Victorian Sheep, and its Transmission by the Sheep "Tick," *Melophagus ovinus*.

The sheep trypanosome, *T. melophagium,* was first encountered accidently in a blood smear by Woodcock, in England, in 1908. It has never been regarded as primarily a disease-producing parasite; but, since it may become relatively numerous in the blood of sheep badly

* Detailed measurements, lists of references, and various other details, have been omitted from these notes, but will appear fully in a technical journal shortly.

infested with sheep "ticks" or keds, it is at least possible that its presence in large numbers may contribute to the loss of condition that is so noticeable in such cases; in this respect it is comparable with the cattle trypanosome, *T. theileri.*

It has since been reported from Germany, Holland, Russia and the Argentine, but has apparently not hitherto been described, either as the adult or the immature (crithidial) form, in Australia.

Ordinarily, it is present in very small numbers in the blood, so that a large number of smears may have to be examined before a single specimen is found. As with the cattle trypanosome, special methods are usually necessary to detect its presence. By applying the concentration technique described in the previous paper, we have examined the blood of thirteen sheep with the following results:—

Five that were heavily infested with keds all revealed trypanosomes; out of five mildly ked-infested sheep, three harboured them, while three young ked-free lambs raised in the laboratory from an early age were negative. Thus, of the ked-infested sheep, 80 per cent. were infected with trypanosomes. Workers abroad, using more complicated methods, have reported a similar degree of infection.

The trypanosome studied by us is large, actively motile, and varies a little in size, some specimens being longer and narrower than others. It varies in length from 40.75 μ to 53.75 μ and in breadth from 2.25 μ to 2.75 μ. Three specimens are illustrated in the accompanying photographs (Plates 2 and 3).

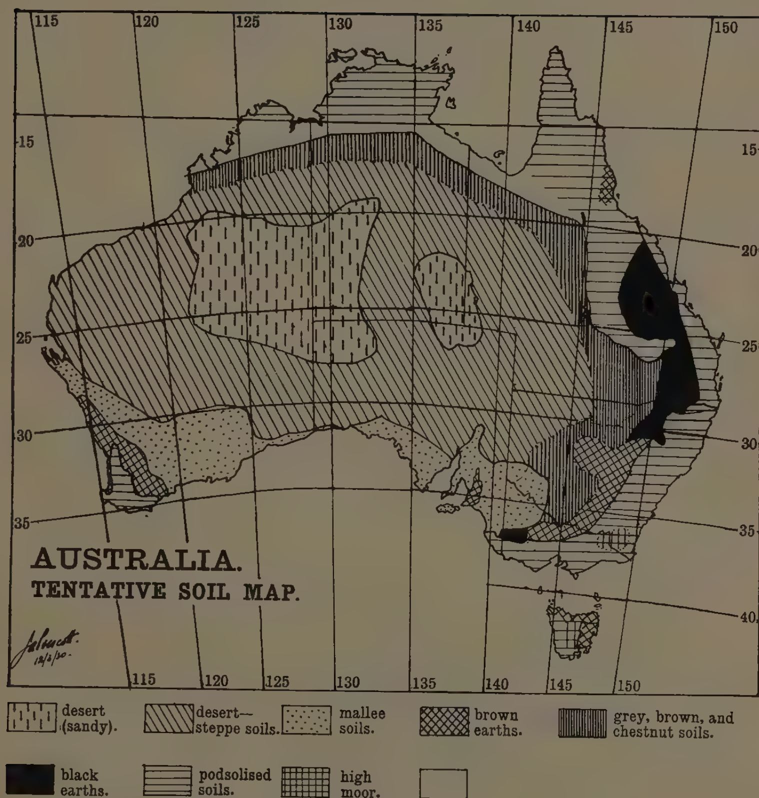
As several workers have shown, this parasite is carried by the sheep ked, in the gut of which the immature (crithidial) forms are present in enormous numbers attached to the lining cells in a thick carpet (see illustration). In spite of this huge infection, the keds do not appear to be at all inconvenienced. We have examined a large number of them.

Contrary to expectation, as recently shown by Hoare, sheep are not infected by direct inoculation during the sucking of blood by infected keds; but are infected by the less common method of ingestion. We have been able to confirm, for the first time, Hoare's claims. On feeding ked-free, trypanosome-free lambs (tested by blood-culture) with an emulsion of the ground-up abdomens of infected keds, we have noted the appearance of trypanosomes in the blood stream six days afterwards. In nature, "clean" sheep become infected by biting at, crushing and swallowing infected keds, in an effort to allay the irritation produced by their blood-sucking.

The highest degree of infection obtained by us was in an artificially infected lamb that had previously had its spleen removed. In this case, two or three trypanosomes were to be seen in every drop of fresh blood examined under a coverslip, while by the concentration technique explained above, up to ten were often obtained per preparation. The accompanying photographs are of trypanosomes obtained from this lamb.

Apart from the theoretical interest of the finding of these two haemoflagellates in Australia, it should prove useful for teaching purposes, since it provides a ready source of living mammalian trypanosomes in a country where such work has usually to be carried out with imported ready-made preparations, in which of necessity the characteristic motility of these interesting and important protozoa is lost.

PLATE 1.



C.2924.

PLATE 2.

TRYPANOSOMES IN THE BLOOD OF VICTORIAN ANIMALS.

FIG. 1.—*T. theileri* from laked and centrifuged defibrinated blood of a cow (natural infection). Fixed with Osmic acid vapours; stained with Giemsa. × 2000.

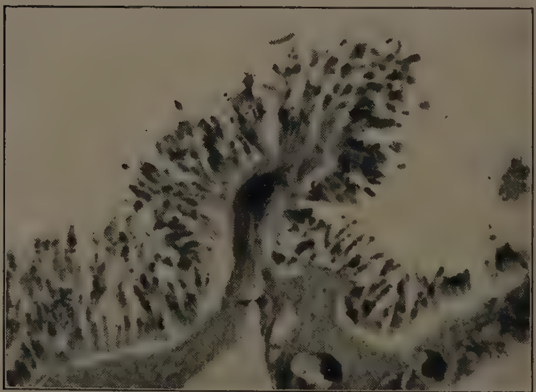


FIG. 2.—Section of the gut of *M. ovinus* showing the intense infection with the crithidial phase of the sheep trypanosome. Fixed by Dobell's modification of Bouin's Picro-formol; paraffin section; stained with Heidenhain's iron haematoxylin. × 1000.

PLATE 3.

TRYPANOSOMES IN THE BLOOD OF VICTORIAN ANIMALS.

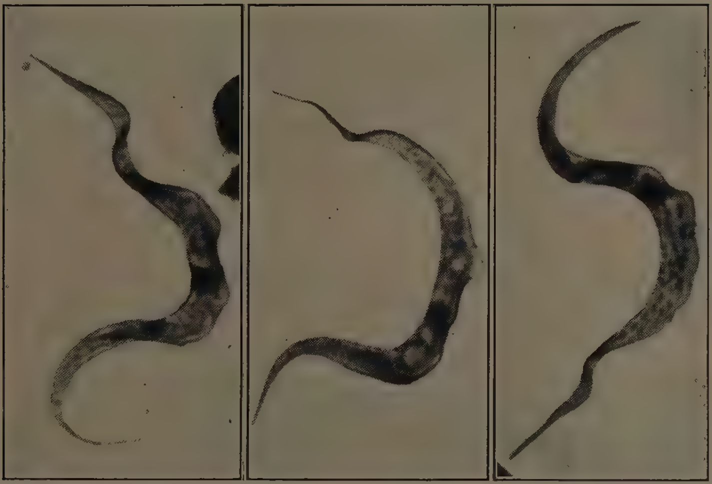


Fig. 3.—*T. melophagium* from laked and centrifuged defibrinated blood of a splenectomised lamb artificially infected by feeding on infected keds nine weeks previously. Fixed with Osmic acid vapours; stained with Giemsa. × 2000.

PLATE 4.

EFFECT OF A SOIL MULCH.

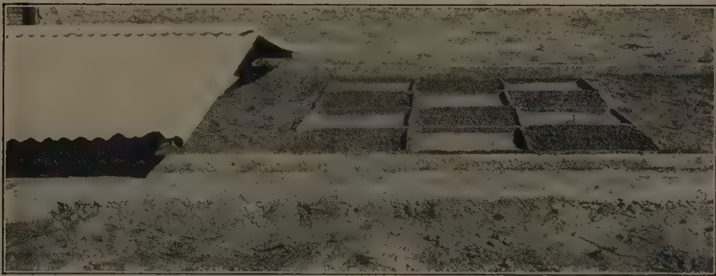


FIG. 1.—General view of experiment after first half was removed, showing sliding cover.

FIG. 2.—View of plots showing positions of thermometers.

A Tentative Soil Map of Australia.*

By Professor J. A. Prescott, Chief, Division of Soil Research.

The recognition of the zonal classification of soil resulting from the work of the Russian school of pedology has of recent years formed a basis for the development of an international system of soil nomenclature. The soils of Australia form a group paralleled in part in the United States, and more particularly in the Kirghiz Republic (Russian Turkestan). The tropical soils probably find a closer parallel in parts of Africa.

The Division of Soil Research of the Council for Scientific and Industrial Research for some time past has been engaged in correlating existing information as regards Australia, and a working tentative soil map prepared in 1928 has been recently revised and is offered at this stage for comment, criticism, and correction. (See Plate No. 1.) It is hoped to revise the map from time to time. The following brief notes are explanatory of the soil types recognized. With the exception of the Mallee group, which appears to be characteristically Australian, all the types have parallels in other countries:—

Desert Soils.—Two main areas of deserts soils are recognized, Gibson's desert and the Arunta desert; these are characterized by long parallel ridges of sand with "spinifex" (*Triodia* spp.).

Desert Steppe Soils.—Include stony desert ("gibbers"), some sand ridge country with spinifex and mulga (*Acacia aneura*), saltbush (*Atriplex* spp.), &c.

Mallee Soils.—Sand ridges, calcareous sands and loams, loamy flats, sand plains covered with Mallee (dwarf and scrub eucalyptus), and heath.

Brown Earths.—Possibly include the Mediterranean type red soils —they usually show signs of incipient podsolisation; the vegetation is usually Eucalyptus savannah. A tropical series undoubtedly occurs, but insufficient information is at present available.

Podsolised Soils.—There appears to be no reason to differentiate between the grey tropical leached soils and the temperate series. Brown earths overlap with the fully leached soils, and near the wet tropical coast of Queensland, lateritised soils are of frequent occurrence:—Eucalyptus temperate and tropical savannah forests form the main vegetation type.

Black Earths.—Appear to be typical in the Wimmera (Victoria), Liverpool Plains (N.S.W.), Darling Downs and Peak Downs (Queensland). There is considerable overlap in places between brown earths, podsolised soils, and black soils depending on topography and parent material. The vegetation is park-like with open grassy spaces.

* Typescript and map received 21st March, 1930.

Grey, Brown, and Chestnut Soils.—Form an important pastoral group of soils—noted in the Riverina and Black Soil Plains (N.S.W.), Western Darling Downs and Rolling Western Downs of Queensland, Barkly Tableland, and Sturt Plain (North Australia), and possibly in tropical Western Australia. The boundaries W. of 140° E. are uncertain. The vegetation is grassy and largely treeless.

High Moors.—Occur on the Tasmanian and Kosciusko Highlands.

Some Australian Poison Plants—Amounts Fatal to Sheep.

PAPER 1.

The Lethal Dose of Hydrocyanic Acid for Ruminants.

By W. L. Hindmarsh, B.V.Sc., M.R.C.V.S.

Erratum.

An error occurs in the first paragraph of this article which appeared in the previous issue, page 12. The ninth and tenth lines of that paragraph should read 22.5 grains and 30 grains respectively.

NOTES.

Catalogue of Scientific and Technical Periodicals in the Libraries of the Commonwealth.

The Council has just published a Catalogue of Scientific and Technical Periodicals in the Libraries of Australia, designed to assist workers in all branches of science and technology in ascertaining where the numerous references met with in the course of their studies may be obtained. It is, for instance, particularly useful in a country of such large distances as Australia for research workers and others to be able readily to ascertain which libraries contain the particular periodicals they desire to see, especially as such periodicals are often comparatively rare.

So that the catalogue might be arranged on the most scientific and up-to-date lines, the services of Mr. E. R. Pitt were secured from the Trustees of the Public Library of Victoria, as General Editor. The task of compilation proved far more formidable than was originally expected, and this fact, coupled with the difficulty in pushing a work of this magnitude and complexity through the press, has occasioned an inevitable delay in its appearance.

The Council is greatly indebted to the various librarians who have so generously assisted in the compilation of the catalogue by furnishing lists and answering the numerous requests for re-checking of queries. In all, 132 libraries throughout Australia, from Perth to Townsville, have co-operated in the undertaking.

Victorian research workers have had to rely hitherto on the catalogue prepared by the late Dr. T. S. Hall and Mr. E. R. Pitt in 1911, which included Melbourne libraries only, and which is, of course, now out of date, except for the older periodicals. That the value of such a work increases as its existence becomes more known, and as its use becomes wider, is evidenced by the fact that the demand in Victoria for the new work has been much greater than it has been in other States where similar compilations have not been hitherto provided for students. The Melbourne University alone has ordered 22 copies for use in its various departments.

All research workers know the irritation caused by a want of knowledge as to where a reference encountered in their studies may be consulted. It may be that the periodical required is in some library quite close at hand where arrangements may be made for its perusal. It may be contained only in the library of some other State, and it is hoped that the co-operation which the various libraries have so cordially given will be extended to the furtherance of facilities for making the desired references available for genuine students. The comparative paucity of material in Australia, and the great distances which separate the centres of learning should prove a stimulus, and not an obstacle to the rendering of mutual assistance.

Besides its primary purpose in enabling the whereabouts of references to be obtained, the catalogue has subsidiary uses. It has been catalogued on the most recent methods adopted jointly by the English and American Library Associations. The difficulty of compiling the catalogue was greatly increased by the diverse and often

bewildering methods followed in the smaller libraries. It is hoped that libraries in general will follow the rules here observed, thus making a uniform practice throughout Australia. To further this desirable purpose, the rules are set out in full in the preface to serve as a guide to librarians. Numerous notes and cross-references are given to enable sets to be properly identified and checked. Special attention has been devoted to the publications of international bodies and to official publications, which prove such a bugbear to the librarian with limited experience. It would appear that good would result if scientific bodies would insist on their librarians becoming acquainted with the methods used in the large libraries in Australia, and adopting them as far as practicable. Again, the completion of sets from the stocks of other libraries by a system of exchange would be facilitated.

In order to extend the use of the catalogue as greatly as possible, the Council has decided to issue the work at a price far below the actual cost of compilation. Copies may be obtained for 10s. each. The catalogue comprises 1,232 pages, and contains 35,282 entries. Very favorable reviews have already appeared in the press.

Antarctic Meteorology—Book by Dr. E. Kidson.

In a previous issue, mention was made (page 60) of the pending publication of a book by Dr. E. Kidson on meteorological observations of the First Shackleton Expedition to the Antarctic. This book constitutes the first work to be accepted for publication under the aegis of the Scientific Publications Committee which administers a small fund that has been set aside by the Commonwealth Government to ensure the publication of Australian work of high scientific value, which was in danger of being lost to subsequent workers owing to the impossibility of ensuring its publication through the normal channels.

Copies of Dr. Kidson's book are now available from the printer. After a discussion of temperatures, clouds, and barometric pressures, the writer goes on to discuss general considerations and points out that the chief value of meteorological observations made in the Antarctic rests in the light they throw on the air circulation of the southern hemisphere, and thence on that of the world. He states that there is no portion of the earth comparable with the Antarctic in size of which our knowledge of the meteorology is so inadequate, that it is obvious that no complete picture of world meteorology can be gained so long as such a gap remains, that the conclusion is rapidly being forced upon meteorologists in all quarters of the globe that their local weather is a function of world conditions, and that it is to be very much hoped that the scientific problems of the Antarctic region will soon again be attacked by properly organized bodies with resources adequate for the purpose. He sounds a note of caution, however, in the statement that he can see no grounds for believing—as many meteorologists and geographers appear to do—that the solution of world problems in meteorology would follow quickly from research in the Antarctic.

The publication is printed in quarto size and contains 183 pages and 17 figures. Copies of it (price 7s. 6d.) are available on application to the Secretary of the Council, 314 Albert-street, East Melbourne.

St. John's Wort—Possibilities of Control by Insects.

Some progress has been made with the investigations of the Division of Economic Entomology on the control of St. John's wort (*Hypericum perforatum*) by insects.

A report on the whole question of the possibilities of such control was made by Dr. Tillyard in the year 1926 (see this Journal, Vol. 1, No. 2 (1927), p. 78). Subsequently, when the Division was formed, one of its officers, Mr. S. Garthside, was detailed to make further studies of the life histories of various groups of insects known to confine their feeding activities to the genus *Hypericum*. Studies of the insect genus *Chrysomela* have been prominent in this work, which has been carried out at the Imperial Bureau of Entomology's "Parasite Zoo," at Farnham Royal, England.

Shipments of three species of *Chrysomela* have recently been sent to Australia and studied at the quarantine laboratories of the Division at Canberra. Encouraging results have been obtained by the officer (Mr. G. A. Currie) responsible for carrying out this last aspect of the investigations. A few adult specimens of the species *Chrysomela didymata* were liberated in October of last year on one plant in a corner of one of the closed organdie compartments in No. 1 insectary. These produced a brood of larvae in December, which entirely defoliated the original plant and those plants immediately surrounding it, and then began to spread out over the other plants in the compartment. During February and March, a second and considerably larger brood arose from these, and a number of this second brood returned to the original plants, which had in the meantime made a good attempt at recovery from the original defoliation, new leaves having appeared on the old stems and a number of new shoots having grown out from the bases. The beetle larvae attacked this new growth and again entirely defoliated the plants. The result of the second defoliation has been that the plants are now entirely dead.

While the foregoing is most encouraging from the point of view of the continuation of the work, it should be realized that much remains to be done before successful results on a large scale in the field may be expected. A scheme of mass breeding likely to be successful in the field still remains to be developed, and it also remains to be seen whether the same results as those obtained in the insectaries will be duplicated under natural conditions outside.

The Freezing and Conditioning of Meat.

In the previous issue, an account was given of the work of the Meat Preservation Committee on the freezing of prime beef. The main conclusion of that work was that beef, provided it is young and of prime quality, does not suffer deterioration in its eating qualities after freezing and subsequent thawing. In the 14th report of the British Department of Scientific Research referred to elsewhere (see page 129) some interesting information along somewhat similar lines is given. Extracts from that report are as follow:—

"As an example of work of more immediate practical application we may call attention to the inquiry on the effects of hanging or "conditioning" meat, which was made at the suggestion of the Sheffield

and Leicester Corporations. The Board* was asked to investigate whether the commonly held view that hanging improved the palatability of meat was correct. One of the difficulties of this investigation was to get a practical criterion of palatability. This difficulty was overcome through the invaluable help of the Household and Social Science Department of King's College for Women, and of Dr. L. H. Lampitt, and the scientific staff of Messrs. Lyons and Company. In both cases teams of judges were appointed, who recorded their judgment of the meat submitted without any knowledge of its origin or treatment before cooking. The pronouncements of these independent teams of judges were in remarkable general agreement, thus leaving little doubt as to the correctness of the conclusions drawn from the experiments."

"The first series of experiments, in which meat was conditioned at a temperature of 41° F. for periods up to ten days hanging, gave clear evidence of an increase in tenderness coupled with no loss in flavour. In the second, more elaborate series of experiments, two temperatures of conditioning were investigated, namely, 32° F. and 41° F. In both cases the results again showed improved palatability, no change in flavour, and a slight improvement in the juiciness and texture of the meat. The first series of experiments seemed to indicate that inferior beef was more improved by conditioning than prime beef, but this conclusion was not confirmed in the second series, and the point requires further experiment."

"The whole investigation led to the conclusion that the most favorable period for conditioning is ten to twelve days at a temperature of 36° F. to 38° F. The Board also obtained the assistance of the expert judges in getting some preliminary indication of the effect on palatability of partially freezing beef (28° F.) and of freezing at low temperatures (14° F.). Prime Aberdeen Angus bullocks were used for this experiment, and the conclusion was reached that the difference in palatability between the two types of frozen beef and the unfrozen control beef was quite insignificant. This suggests that the prejudice against frozen beef may be due to inferiority in the original quality of the meat rather than to the effects of freezing."

The Feeding of Sheep for Wool Production.

One of the first investigations initiated by the Division of Animal Nutrition was a study of the chemical constitution of wool fibre. The object of this work was to examine wool with a view to determining whether there were any particular materials or combination of materials which it contained, and which was thus essential to the sheep.

The results of this work have been published in the Council's Bulletins Nos. 38 and 39. Briefly, they indicate that a very important constituent of wool is the complex sulphur-bearing amino compound known as cystine. Using this determination as a basis, the next logical step was to carry out investigations, firstly, on the feeding of cystine rich supplements to sheep, and secondly, on the deletion of cystine from the diet. In regard to the second matter, the Division demonstrated some time ago that "wool break" is usually caused by nutritional distress caused by a diet deficient in cystine, and that it may usually be obviated by supplementary feeding with cystine rich proteins.

* The British Food Investigation Board.

Some interesting results in the other direction have recently been obtained at the Division's Field Station that has been established at "Meteor Downs," Queensland. The pastures of the district are luxuriant in appearance, but were judged by the Division to be deficient in protein (and thus probably in cystine) owing to the fact that in practice they do not appear to be so nutritious as their luxuriance would warrant. It was accordingly decided to try the effect of feeding new-born lambs (and ewes) with cystine rich supplements, and to measure the effect by a comparison with a similar group of new-born lambs and their mothers treated in a similar manner as the experimental lambs, with the single exception that the control animals were not given the cystine rich supplements. The supplement chosen was sterilized blood meal. Each group contained approximately 100 lambs, and each was grazed on equal-sized paddocks. Further, each group was changed over as between paddocks once per week. The tentative results of the first shearing of the two groups of lambs have just become available, and indicate that on an average each fleece of the lambs that received blood meal is about 20 ounces heavier than the average fleece of the lambs which received no blood meal. The cost of the supplementary feeding averaged less than 10d. per head. The net result, therefore, is that at this particular station, 20 ounces of wool were obtained for an expenditure of less than 10d.

Of course, the Division realizes that there is far too little blood meal available in Australia to treat the whole sheep population of the continent. Moreover, many of the pastures on which large numbers of sheep are fed are such that the feeding of blood meal would not be warranted. However, the results obtained at "Meteor Downs" lend encouragement to the search for other sources of cystine rich materials. It is quite possible that large quantities of cheap yet rich cystine-bearing material will be found as a result of the survey of protein materials on which the Division is now engaged.

British Department of Scientific and Industrial Research—Annual Report.

Copies of the 14th Annual Report (for the year 1928-29) of the British Department of Scientific and Industrial Research have recently become available in Australia. It would be impossible to cover the numerous activities of the Department in a short note, and so the following paragraphs have been confined to mention of new activities and to matters of interest chosen somewhat at random, but nevertheless such as will serve to give an indication of the very wide field of the Department's work.

The comprehensive investigations of the Department in regard to fuels, the preservation of foods, the operations of the National Physical Laboratory, radio research, &c., are now widely known, and, therefore, hardly need discussion. A new development is the appointment of a Geophysical Research Committee to advise on the investigations of geophysical methods of survey carried out by the Geological Survey, to consider and report upon the possibility of taking steps to encourage other investigators of such methods at Universities elsewhere, and to encourage the design and production of suitable British instruments. Another new body that has been set up is the Steel Structures Research Committee, which has been established to review present methods and

regulations for the design of field structures, including bridges, and to investigate the application of modern theory of practice to the design of such work.

A Committee has also been set up to examine a suggestion that a national locomotive experimental station should be established under the auspices of the Department. The British railway companies have urged that the establishment of such a station would be of national advantage in that it would lead to economies in the fuel consumption of locomotives.

As a result of the work of its officers, during the year the Department has applied for twelve patents covering such matters as the manufacture of beryllium oxide, methods of treating tars, heat resistance alloys, hygrometers, distance thermometers, high pressure gas reaction vessels, and apparatus for chemical and physical processes. Mention is made in the report of the growing interest taken by various sections of industry in the work of the Department. All the research organizations of the Department, but particularly the Building Research Board, have received an increased number of requests for special investigations and for advice on industrial problems, and the number of tests and special tests at the National Physical Laboratory have exceeded any previous year.

In the field of low temperature distillation of coal, the full scale plant erected to the Department's design at the Gas, Light, and Coke Company's plant at Richmond is discussed. The retorts of this plant are fabricated of a special mixture of cast-iron and have shown no signs of distortion after fourteen months' continuous operation. This is considered to be an important point, as the commercial success of the process will very largely rest in the life of the retorts.

As a result of the Empire Marketing Board's capital grant of £30,000, and an annual payment in addition, the work of the Forest Products Research Board has been considerably extended, and now covers studies of the variations in wood structures with respect to variations in properties, the kiln seasoning properties of the home-grown timbers, seasonal shrinkage, the fibre saturation point, the alleged deterioriation of timber subsequent to drying, the mechanical and physical properties of timbers, the deterioration in strength of timber at various stages of decay, tests of timbers in structural sizes, preservation, and the working and finishing qualities of wood. An interesting investigation has been completed by the Board on behalf of the furniture trade, the object of which was to discover the optimum conditions to which to season furniture timbers, taking into account the moisture content of the wood under the various conditions of atmospheric humidity met with in different environments, for example, in a heated living room or in a bedroom at different seasons of the year. Work has also been undertaken on the powder-post beetle (*Lyctus sp.*), and satisfactory methods of control have been demonstrated to the trade. Incidentally it has been found that the size of the pores of the timber as compared with the minimum width of the *Lyctus* eggs determines whether or not a species is liable to attack.

The plating industry is being helped by a Departmental Research Committee which has been appointed to make arrangements for comprehensive researches bearing on industrial problems of electro-deposition of special interest to Government Departments, and studies have

been carried out on the plating of nickel, iron, cadmium, and aluminium, and an investigation is being made into the fundamental aspects of adhesion and internal stresses in electrode deposits.

The Chemical Research Laboratory is engaged among other things on a study of tars obtained by the low temperature distillation of coal, particularly from the point of view of the chemical and physical properties of the various resins they contain.

At the British Museum interesting work is being carried out on the development of methods for the restoration of damaged pictures and museum articles and their preservation. In the case of pictures and drawings the value of chloramine-T as a mild bleaching agent in dilute aqueous solution has been amply demonstrated.

The total net expenditure of the Department for the year ended 31st March, 1929, was £485,450.

Empire Marketing Board—Reports.

Since the last reference to Empire Marketing Board publications was published in this Journal (Vol. 2, No. 4, p. 250) five further reports have appeared. These are as follows:—

(*a*) *E.M.B. No.* 21. "*Wool—A Study of the Fibre,*" by S. G. Barker, Ph.D., &c., Director of Research, British Research Association for the Woollen and Worsted Industries. This publication contains 166 pages of matter, including illustrations such as microscopic sections and X-ray photographs of the wool fibre. It is designed to serve as a summary of the existing state of scientific knowledge regarding wool, and indications of the directions in which scientific knowledge is lacking. Quoting from the preface "it is written, not only for specialists, but also for agriculturists, pastoralists, and administrators interested in wool problems; and especially perhaps for new recruits to biological research while looking for fresh fields to conquer and new problems of interest to be solved and of economic importance to the Empire."

(*b*) *E.M.B. No.* 22. "*Demand for Cheese in London.*" This publication constitutes the Empire Marketing Board Economic Section's report of an investigation into the retail marketing of cheese in London.

(*c*) *E.M.B. No.* 23. "*The Growing Dependence of British Industry upon Empire Markets,*" by F. L. McDougall, C.M.G. (Representative of Australia on the Empire Marketing Board). This paper has been published as what is regarded as a valuable individual contribution to a controversial subject and not as an approved statement of any official view of the Empire Marketing Board on that subject.

(*d*) *E.M.B. No.* 24. "*Report on Insect Infestation of Stores to Cacoa,*" by J. W. Munro, M.A., D.Sc., and W. S. Stock, M.A. This publication constitutes a report on work carried out by the Imperial College of Science and Technology at the Research Laboratories at Slough subsidized by the Empire Marketing Board for the special conduct of research into the insect infestation of stored products. Of more direct interest to Australia is the work of the laboratory in regard to the infestation of dried fruits.

(*e*) *E.M.B. No.* 25. "*Indian (Sunn or Sann) Hemp*"—a memorandum on its production and utilization prepared by the Imperial Institute in co-operation with its Advisory Committee on Vegetable Fibre. Sunn hemp is the fibre of *Crotalaria juncea* which is a very useful plant for rotation with cotton, sugar cane, and maize. The fibre

is quite a satisfactory substitute for true hemp which is prepared from *Cannabis sativa,* but the retting processes involve a considerable amount of labour and are therefore costly.

Central Australia—Concession Fares to Scientists.

The Commonwealth and the State Railways concerned have recently reached an agreement whereby zoologists, botanists, geologists, ornothologists, ethnologists, and other scientists will be enabled to visit such places as Central Australia and the Nullarbor Plain at two-thirds fare.

Recent heavy rains have brought new life into the interior and added to the interest of a visit. Moreover, during the winter months the climate of the areas under discussion is ideal and affords an excellent opportunity of exchanging the cold and wet of a southern winter for warmth and sunshine. If desired, the Commonwealth Railways will undertake all arrangements for scientific parties, including camping and transport facilities away from the railway. Further information is obtainable on application to the Secretary, Commonwealth Railways, "Chelford House," Flinders-lane, Melbourne.

Visit of Dr. Rivett to Europe.

The Chief Executive Officer of the Council, Dr. A. C. D. Rivett, left Melbourne per the s.s. *Demosthenes* on the 21st March last. He will visit England and the Continent via South Africa.

While in Great Britain, he will discuss a number of matters, such as research in irrigation, fuels, wool production and utilization, the storage and transport of foods, &c., in which close co-operation with the various research organizations in Britain is most desirable. He will also inquire into several other matters, such as power alcohol and the production of liquid fuels from coal, at the specific request of the Government. Incidentally, too, he will attend several scientific congresses on matters of interest to the Council.

It is expected that he will be absent from Australia for some six months or more. During his absence, Sir David Masson, K.B.E., F.R.S., &c., will act as a member of the executive committee of the Council.

Recent and Forthcoming Publications of the Council.

Recent publications of the Council have been:—

Pamphlet No. 17—"The Mineral Content of Pastures—progress report on co-operative investigations at the Waite Agricultural Research Institute."

Third Annual Report—for the year ended 30th June, 1929.

Catalogue of Scientific Periodicals in Australian Libraries—(1208 pages).

The publications which are now in the press and which will be issued shortly are as follows:—

Bulletin No. 44—"Investigations on Spotted Wilt of Tomatoes," by G. K. Samuel, M.Sc., J. G. Bald, B.Agr.Sc., and H. A. Pittman, B.Sc.Agr.

Bulletin No.   —"A Soil Survey of the Woorinen Settlements, Swan Hill Irrigation District, Victoria," by J. K. Taylor, B.A., M.Sc., and F. Penman, M.Sc.

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